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The

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The Papua and New Guinea Agricultural Journal, Vol. 12, No. 4, March, 1960.

ERRATA.

Page 149, Plate 1.—" Open-pollinated spacing. Pruning trial . . . " should read " Open-pollinated spacing-pruning trial . . . "

Page 160, Plate 7.—" Plant 7 " should read " Plate 7 ". " inverted clone development " should read " inverted cone development ".

Page 160, Plate 8.—" Clones planted 18 feet by 16 feet " should read " Clones planted 18 feet by 6 feet ".

Page 191, Appendix A.—" Bush foods. Tulip-Gnetum Genomon " should read " Gnetum Gnemon ".

Former Issues of *Gazette* and *Journal*

The following numbers of the *Agricultural Gazette* have been issued :

New Guinea Agricultural Gazette—

Volume 1, Number 1.
Volume 2, Numbers 1, 2 and 3.
Volume 3, Numbers 1 and 2.
Volume 4, Numbers 1, 2, 3 and 4.
Volume 5, Numbers 1, 2 and 3.
Volume 6, Numbers 1, 2 and 3.
Volume 7, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Gazette—

Volume 8, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Journal—

Volume 9, Numbers 1, 2, 3 and 4.
Volume 10, Numbers 1, 2, 3 and 4.
Volume 12, Numbers 1, 2 and 3.

Copies of all numbers of the *Gazette* to Volume 7, No. 4, are out of print.

PLATE 1.—*Open-pollinated spacing. Pruning trial at 11 years old, planted 12 feet on the triangle.*

CACAO IMPROVEMENT PROGRAMME, KERAVAT

L. A. BRIDGLAND.

The thriving cacao industry in Papua and New Guinea has drawn all its planting material from the comparatively few trees of varied stock which survived the war. In this paper, Mr. Bridgland, until recently Agronomist-in-Charge at the Lowlands Agricultural Experiment Station at Keravat, near Rabaul, discusses the origin of the Trinitario complex in New Guinea, the scope for improvement and the objects and methods of the development programme at Keravat. Mr. Bridgland also discusses the "clonal seed" production programme, the development of clones for commercial use and the methods being used for the development of uniform hybrids through seed.

ORIGIN OF NEW GUINEA CACAO.

THE present cacao population in Papua and New Guinea probably came from stock introduced from Trinidad by way of Java, Ceylon and Samoa (Green, 1938). There is also some evidence to suggest a direct introduction from Venezuela at one stage (Henderson, 1951). These introductions began at about the turn of the century and continued until 1907. The only subsequent introduction was from Java in 1932. The New Guinea Department of Agriculture assembled planting material from certain known sources, and some of this stock was used for plantings at the then Demonstration Plantation at Keravat during the 1930's. No systematic breeding was carried out and different types became thoroughly mixed through inter-crossing. The original parent trees in the Rabaul Botanic Gardens were completely destroyed during the war and the plantings at Keravat were decimated.

In the immediate postwar years, Keravat became the major experiment station for lowlands crops in the Territory and a collection of cocoas was re-established by F. C. Henderson. These early postwar plantings were in the form

of progeny trials from open-pollinated selected trees covering an extremely wide range from near Amelonado and Calabacillo types to pure Criollo. The parent trees were selected by Henderson from the remnants of cacao surviving at Keravat and various plantations near Rabaul. Taking the cacao in all parts of the Territory, the sum total is a Trinitario type.

The present programme is based almost entirely on Henderson's progeny trials which have provided a large variable population growing under the best plantation conditions at wide spacings and for which individual tree yield records have been kept from first bearing.

The early open-pollinated progeny trials had great value, quite apart from supplying a useful cacao population. Henderson's original parent trees were selected on the basis of vigour, disease and pest resistance, apparent yielding ability and pod and bean characters. Indeed, anything which survived the war must have possessed remarkable vigour. However, the performance of the parent trees over their lifetime must unfortunately remain unknown.

It soon became apparent that the progenies from the different parent trees showed a wide variation in performance. Certain trees gave early and high-bearing progenies, but, since the male parentage was unknown, this information could not be put to direct practical use beyond indicating that, with control of male parentage, clonal seed of a high order of performance could be produced. This is an objective worth working for. These trials provided some information on the general combining ability of a large number of trees and this information is of great value.

Certain parent trees yielded extremely poor progenies. One tree in particular gave a completely defective progeny, although normal itself except for the presence of what we have tentatively termed "embryo failure". "Embryo failure" is referred to again in greater detail later in this paper. Such information formed the basis of the Department's recommendation to planters that where tree selection is practised on the plantation—

1. At least 20 trees should be selected ;
2. The seed of these selected trees be bulked and three seeds planted per point with subsequent removal of the two least vigorous ; and
3. Where cacao is planted out from a nursery, any seedlings lacking in normal vigour be discarded.

SCOPE FOR IMPROVEMENT

Observations and measurement indicate that cacao is capable of radical improvement in every respect, including earliness of bearing, yielding ability, cocoa butter content of bean, bean size and flavour. There is also a big variation between trees in susceptibility to Black Pod Disease, although no really serious diseases of cacao have appeared yet in the Territory.

To indicate the potential improvement in yielding ability the field figures for Area 405 are quoted. Area 405 was one of Henderson's progeny trials planted in July, 1948. It covers an area of approximately 10 acres. A severe drought in 1950 caused complete defoliation, and a very heavy capsid attack in 1951-52 largely destroyed the early crop, so that yield recording did not commence until 1953. The figures in Table I cover the total yield from 1953 to 1958, excluding edge trees and excluding 20 of the highest yielding trees, which were selected in 1954 and subsequently butchered for cuttings.

The percentage of yield contributed by the upper bracket of trees is illustrated by the graph in Fig. I. The yield increase which would theoretically result from entire plantings of a narrower or wider proportion of the highest yielding trees is illustrated by the graph in Fig. II.

The figures from Area 405 give some idea of the variation in yield performance of individual trees in a block of seedling cacao. If it could be assumed that there is no reason why all the trees should not yield as well as the best, and having regard to the fact that if all the trees yielded as well as the best five per cent. there would be an increase in yield of the order of 140 per cent., it would appear to be possible to attain yields of 2,000 lb. dry beans per acre per annum by vegetative propagation of the best trees in our existing seedling population.

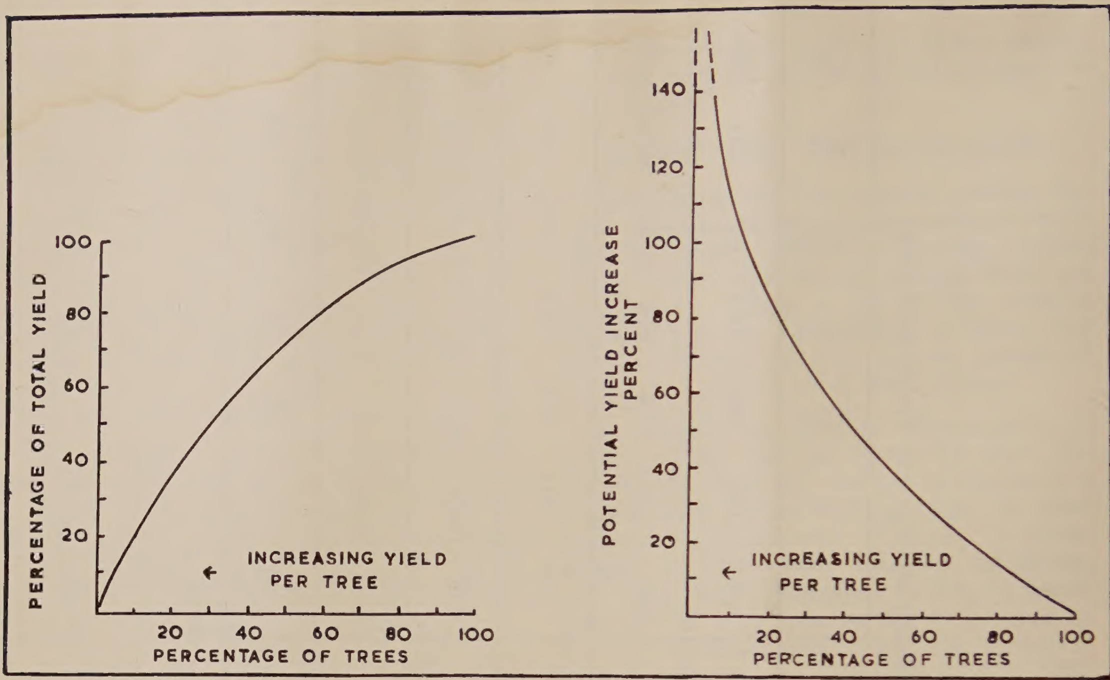
A criticism which may be levelled at the above deductions is on the basis of our calculation of yield of dry beans by using the conversion factor of 10.5 pods/lb. dry beans for all yield classes. Taken over all, the conversion factor is accurate for the trial, but it might be expected that there

TABLE I.

Area 405—Frequency Distribution—Pods Per Tree Yearly Average over Period 1953-1958.

Yield Class Pods/Tree.	131 to 140	121 to 130	111 to 120	101 to 110	91 to 100	81 to 90	71 to 80	61 to 70	51 to 60	41 to 50	31 to 40	21 to 30	11 to 20	0 to 10
Number of Trees	1	0	3	10	17	31	64	105	199	284	375	357	214	126
Running Total .... (Trees)	1	1	4	14	31	62	126	231	430	714	1089	1446	1660	1786
Percentage of Total	0.05	0.05	0.2	0.8	1.7	3.5	7.1	12.9	24.1	40.0	61.0	81.0	93.0	100.0
Number of Pods	135	0	377	1055	1624	2651	4832	6878	11045	12922	13313	9104	3317	693
Running Total .... (Pods)	135	135	512	1567	3191	5842	10674	17552	28597	41519	54832	63936	67253	67946
Per cent. of Grand Total	0.2	0.2	0.8	2.3	4.7	8.6	15.7	25.8	42.1	61.1	80.7	94.1	99.0	100.0

Mean = 38.044 + or — 12.006.



FIGS. I *and* II.

would be a decrease in pod value with increasing pod yield. Naturally, the trees in the highest-yield classes have received closest attention and our measurements indicate that the conversion factor is accurate for the trees with high pod yields.

The selections made in the particular trial are listed in Table II with their pod values :

selected, have pod values which do not differ significantly from the pod value for the trial as a whole.

Objects

In the first instance our aim is to produce early-bearing, high-yielding types without weakening other desirable characters such as high fat content, flavour, vigour and disease resistance.

TABLE II.

Pod Values of Trees Selected in Area 405.

Selected Tree.	Pod Value.	Selected Tree.	Pod Value.	Selected Tree.	Pod Value.
K5.101	9.8	K17.101	9.2	K23.102	9.6
K6.101	8.4	K19.101	11.3	K23.103	10.6
K11.101	7.6	K19.102	11.0	K23.104	12.4
K12.101	10.3	K22.101	9.1	K23.105	10.9
K15.101	10.5	K22.102	7.5	K23.106	9.7
K16.101	10.5	K23.101	11.8	K23.107	12.3
K27.101	11.7	K27.102	8.8		

Mean Pod Value = 10.15.

The above pod values are based on determinations from 30 to 50 pods measured at three or four different times of the year.

Examination of the other trees with high pod yields, which for various reasons were not

For the present, it is our intention to retain the Trinitario character and, in actual fact, in the short term we have no other alternative without large-scale introductions and this we will not do. Our first aim is to meet the above

requirements on a broad base of genetic material and as times goes on the emphasis can be swung closer to the Forastero type if this is what the market demands. Meanwhile, we aim at considerably less variation in nearly all characters than exists in our present cacao population.

When yield requirements are met, the emphasis of our breeding programme will shift to cocoa butter content and flavour characters, provided that no other serious problems arise in the meantime.

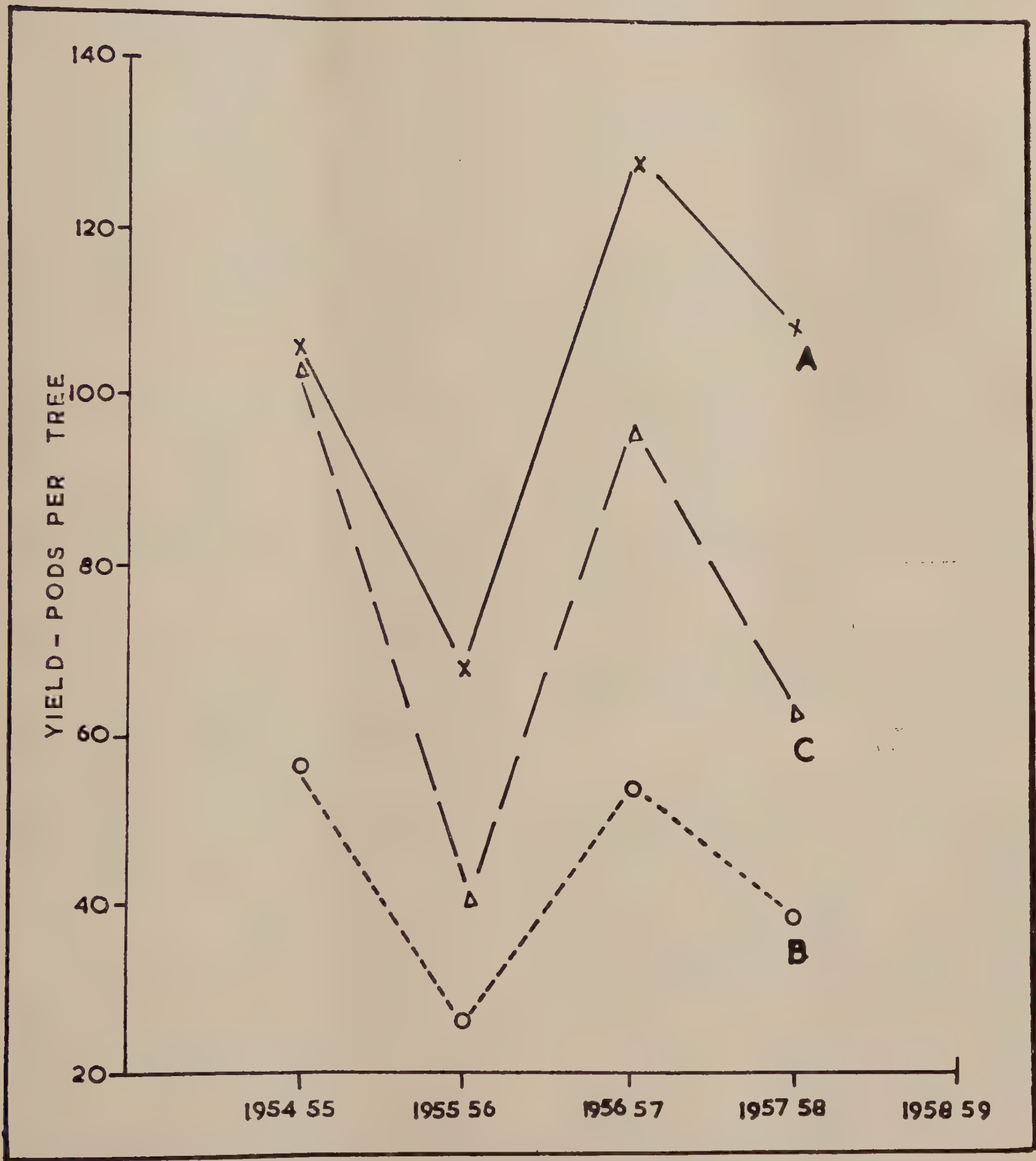


Fig. III.

In translating these objects into an actual programme, three separate avenues have been followed concurrently :—

(1) The development of "clonal seed".

(2) The development of clones for commercial use as such.

(3) The development of hybrid seed.

SELECTION

Each of the above avenues is dependent in the first instance on selection of suitable parent material. The bases for such selection are given below.

Pod and Bean Characters

Selection on the basis of pod and bean characters is a simple and straightforward matter. We have not placed the same emphasis on "pod value" (the number of pods required to make one pound of dry beans) as workers in many other parts of the world, because we can see no particular objection to somewhat smaller pods if bean characters and yielding ability are satisfactory. In fact, to overemphasize pod value would mean discarding a great deal of our highest-yielding material. However, anything with a pod value higher than 12 has not been selected. Most of the selections have a pod value of eight to ten although a few are as low as seven.

Minimum standards of bean size have generally been laid down by manufacturers at 450 beans per lb. Most of our selections have a bean value of 300 to 400, but it is as low as 250 in some cases.

Flavour and cocoa butter content were disregarded in the early stages of our selection work for the reason that the nib belongs to the second generation and both characters are therefore likely to be influenced by male parentage. However, any selected tree with a particularly low cocoa butter content was discarded. Further culling will be carried out on the basis of clone testing trials (see page 158) which have been designed to throw light on the influence of male parentage on nib characters.

Shell Percentage

Any tentative selections found to have a particularly high shell percentage were also discarded. The average shell percentage of New Guinea beans is some three to four per cent. higher than in West African beans and is therefore a point of some importance in our breeding programme.

Vegetative Characters

For the most part, vegetative characters have not been made a cardinal point in our selection programme. Early results suggested that not all vigorous seedling trees were vigorous as cuttings (e.g., K24) and that certain trees which were not particularly vigorous themselves were surprisingly vigorous as cuttings (e.g., K17.101). Therefore, in selecting parents, we have been satisfied if a tree possessed reasonable vigour. It appears that trees with an erect type of fan growth from the jorquette produce better-shaped plants as cuttings than those with a more straggly habit, but this has not played a part in our selection work.

Pest and Disease Resistance

This could scarcely be considered because we have no serious pests or diseases on the station except for "Black Pod" and a few capsids. Any tree which was noticeably susceptible to Black Pod or capsid damage was not selected. However, we will depend on the results of our clone-testing trials for a final culling on this basis.

Early Bearing

This character has received great emphasis because of its practical importance to the grower. Due to a favourable combination of type and conditions, cacao appears to come into significant bearing considerably earlier here than overseas. This is illustrated in Table III.

TABLE III.

Area 304 *—*Planted March*, 1948.

Age.	Yield Dry Beans/Acre (lb).
To 3 years	281
3-4 years	503
4-5 years ...	627
5-6 years	976
6-7 years	1,147
7-8 years	607
8-9 years	1,268
TOTAL	5,409

(* Open-pollinated progeny trial involving 10 acres, approximately.)

Notwithstanding the above, individual trees have shown a far greater tendency to early bearing and the most vigorous of these have been selected where pod and bean characters were also satisfactory. As an indication of the effect of the early high yielders on the early yield pattern, a frequency distribution was drawn up for the total yield to the age of four years and six months for the area of cacao referred to in Table III. In the high-yielding bracket of trees, this showed that 10 per cent. of the trees produced 30 per cent. of the yield and at the other end of the scale, that is, the low-yielding bracket, 30 per cent. of the trees contributed only 6 per cent. of the total yield.

Risks are involved in selecting for precocity. It is likely that high-yielding, precocious types may have a shorter economic life span, although this has not been proved. Not all selections made at Keravat are precocious and we have deliberately selected a proportion of "later" maturing trees, although even these are by no means "late" by most overseas standards.

Selecting for Yielding Ability

The yield of any tree is influenced by many factors apart from its inherent yielding ability. Locational factors involving soil fertility, water relations, exposure to wind and level of maturation, presence or absence of shade and competition effects for nutrients, water and light may flatter or obscure the true inherent yielding ability of a tree. Thus the scientific basis for selecting on inherent yielding ability is not particularly sound. The general performance of the Trinidad selections caused us to give careful consideration to the question of minimizing the effect of factors which tend to obscure the inherent yielding ability of individual trees. Thus, in planting up areas for selection work, attention was paid to the following points :—

(1) Only areas without significant topographical irregularities and where any pretreatment was uniform were chosen for planting. The "soil" at Keravat is an immature volcanic ash and, while there may be minor variations in water relations, the soil type does not vary greatly in nutrient status over short distances.

(2) A uniform shade canopy was established.

(3) Comparatively wide spacings were used.

(4) Edge trees, which we have shown to yield some 50 per cent. higher (at 10 years old) than inside trees, were ignored.

(5) Age at which selection was carried out was between the fifth and seventh year, with emphasis on the period of fifth to sixth years. At this stage many precocious types are selected and also later maturing trees—but competition effects have not assumed great importance.

The importance of competitive effects is not well understood, but is likely to be a major determinant of individual tree performance.

Effects of Competition and Tree Size

Measurements of girth have been recorded on a random sample of 26 cacao trees in Area 304 at different stages of growth and these have been correlated with current yield at the time of measurement.

The first girth measurements in 1952 were made at ground level but because of the distortion caused by the tendency of some trees to "buttress" at ground level, subsequent measurements were taken half-way between ground level and the jorquette. Results are as follows :—

Correlation between girth in 1952 and total yield up to 17.9.52, $r = 0.240$ (Trees four years old).

Correlation between girth in 1955 and yield for 12 months ended 30.6.55, $r = 0.531$ ** (Trees seven years old).

Correlation between girth in 1958 and yield for 12 months ended 20.6.58, $r = 0.714$ *** (Trees ten years old).

It is clear, therefore, that the vegetative vigour of a cacao tree becomes increasingly important as a determinant of its yield as the tree ages. This might be due to two factors :—

(1) Yield in the early years may be determined by genetic factors for precocity independent of the factors controlling vegetative vigour. The ultimate yielding capacity of the tree, however, is largely dependent on its size.

(2) Inherent yielding capacity of the tree may be largely independent of its vegetative vigour, but as the tree grows older the bigger trees have a competitive advantage over the smaller ones, which tend to become suppressed and outyielded.

In an attempt to assess the importance of competition against tree size as such, the following groups were selected from a sample on which girth measurements were made in 1954. This gave a rough measure of individual tree vigour. The relative vigour of individual trees was calculated by dividing their girth by the mean girth of the four surrounding trees, which, when multiplied by 100, gives a "relative vigour index".

A. Trees bigger than those surrounding them—i.e., Relative Vigour Index greater than 100 (11 trees).

B. Trees smaller than those surrounding them—i.e., Relative Vigour Index less than 100 (23 trees).

C. Trees about the same size as those surrounding them—i.e., Relative Vigour Index about 100 (nine trees).

The girth of trees in group (C) was approximately the same as those in Group A.

Average girths in 1954 were :—

Group (A), 17.1 inches.

Group (B), 13.1 inches.

Group (C), 16.7 inches.

It was not possible to find another group similar in girth to Group B with equally sized surround trees.

TABLE IV.

Increase—girth 1954-58.

	Girth in inches.		Per cent. Increase
	1954	1958.	
Group A	17.1	20.9	22
Group B	13.1	14.5	11
Group C	16.7	19.4	16

This suggests that differences in size become accentuated as the plantation ages and that these differences may be to some considerable extent due to differential competition.

TABLE V.

Change in Relative Vigour Index.

	R.V.I. 1954.	R.V.I. 1958.
Group A	114.0	122.6
Group B	82.1	76.6
Group C	100.8	98.7

This result gives further support to the above conclusion.

Yield Trends

The yields of the trees involved for the four years are shown in the graph (Fig. III). This indicates that there is a marked correlation between size and yield in the early stages, and that competition becomes increasingly important as the trees grow older, particularly among the larger trees.

TABLE VI.

Yield and Vigour Correlations.

	Corr. Coeff.—Yield and Girth, 1958.	Corr. Coeff.—Yield and R.V.I., 1958.
A	0.011	0.235
B	0.352	0.689***
C	- - - 0.145	- - - 0.009
A + B	0.606***	0.790***
A + C	0.321	0.610**
A + B + C	0.484	0.721***

The consistently higher correlations for relative vigour index indicate that competition is probably important, although the differences between the correlation coefficients are not statistically significant.

Thus, it would appear possible and likely that selection at too early an age would differentiate only precocious types and selection at too late an age would select to a greater or lesser degree for competitive ability than for inherent yielding ability. Such trees would not necessarily reproduce a respectable yield per acre when grown as clones under equal conditions of competition.

Taking all the above considerations into account as far as possible, some 60 trees have been selected and propagated for clone testing.

Future Selection Work

When the progeny of clonal and hybrid seed gardens come into bearing, further selection work will be carried out. The possibilities of our existing population have been largely exhausted. Meanwhile, a trial has been laid down designed to provide more accurate information on the relationship between earliness of bearing, vegetative vigour and inherent yielding ability. This trial is in the form of a randomized block with four replications of plots of random cacao seedlings at spacings of 12 feet, 15 feet, 17 feet 2 inches, 20 feet and 24 feet. This trial is now two years old. Individual tree yields and vigour are to be measured—yield at every harvest and vigour at 12-monthly intervals.

DEVELOPMENT OF CLONAL SEED

The term "clonal seed" is used here to denote the progeny of the crossing of two clones. Although this is not an exact usage, it has become a generally accepted term.

For the past few years, Keravat has been called on to supply 60,000 to 80,000 pods per annum for planting. Having no alternative, we have been compelled to distribute open-pollinated material from high-yielding blocks. Our clones are not yet ready for distribution and even if they were the size of the Territory and the scattering of our cocoa-growing areas around a huge coastline and throughout a large number of small islands makes the distribution of clonal material extremely difficult. Under the circumstances we have looked for methods of improving the stock through seed. Our long-term approach to this is through the hybrid seed programme discussed below, but in the meantime it was thought probable, from the results of Henderson's open-pollinated progeny trials, that the crossing of certain selected clones would yield a reasonably uniform and improved progeny. Figures indicating the variation in yield performance of progenies from the different parent trees from one such progeny trial are set out below :—

TABLE VII.

Area 405—*Planted July,* 1948.

(10 acres approximately)

(4 Replications of the progeny of 18 Selected Trees—Randomized Block)

PROGENY Descending Merit	YIELD—lb. Dry Beans/Acre 1953-1954	1954-1955	1955-1956	1956-1957	1957-1958	MEAN
K6	830	1,548	970	1,885	900	1.227
K23	1,023	1,667	878	1,555	824	1,189
K25	785	1,389	766	1,420	648	1,002
K12	809	1,293	745	1,434	690	994
K5	767	1,214	743	1,468	800	978
K17	762	1,265	814	1,291	646	956
K20	754	1,170	678	1,404	640	929
K19	626	996	694	1,447	803	913
K11	673	1,093	767	1,271	613	883
K13	514	1,052	629	1,467	716	876
K26	715	1,127	603	1,263	449	831
K16	662	1,103	621	1,130	550	813
K21	614	1,051	579	1,045	437	745
K14	712	1,069	585	873	408	729
K24	414	842	414	1,287	521	696
K27	475	778	482	887	531	631
K9	390	762	406	917	345	564
K10	189	518	378	475	251	362
Mean	651	1,108	653	1,253	594	852

Analysis of Variance

Differences between—

(*a*) Parents.

(*b*) Years.

(*c*) Replications.

Significant at 0.1 per cent. level.

(Difference for significance between parents at 5 per cent. level = 150 lb. dry cacao/acre.)

It will be seen from the above figures that the best progenies yielded at a rate of some 40 per cent. to 44 per cent. better than the mean. In the nature of Henderson's early selection work, many more or less isolated trees or at least trees, the pollination of which would have come from a restricted source, were selected. This applies particularly in the case of K23 which is self-incompatible. There seems to be no reason why the chance male parentage of this tree cannot be improved on by deliberate selection and, naturally, this number has been used with a variety of male parents in clonal seed gardens.

At all events, the likelihood of a cross of two selected clones giving seed of poorer potential than bulk unselected seed is remote and there is a likelihood of substantial gain in a proportion of the crosses. Pairing a self-incompatible with a self-compatible parent in seed gardens and using the incompatible clone as a source of seed for planting may provide the quickest way of producing improved seed in commercial quantities. Insufficient is known regarding the existence of cross-compatibility between self-incompatible clones in our population to make use of this for the present.

Some 65 seed gardens have been planted at Keravat. The method is empirical, seed gardens being established as the parent trees were propagated. It would of course be desirable to plant all seed gardens in isolation, but this is impracticable. In the first gardens established there was a scarcity of self-compatible clones. Gardens took the form of a single line of a self-compatible clone with two surround lines of the self-incompatible parent. Two lines of robusta coffee were planted between seed gardens to form a rough barrier. This design is hardly satisfactory. As material from self-compatible clones became available in greater quantity, the gardens were designed with self-incompatible plots with a triple compatible surround.

The pairing of clones was highly empirical. Pairings between both similar and divergent types have been made. Where a clone appeared to be weak on a particular point it was paired with a clone in that point.

The clonal seed gardens are now coming into bearing and at a later date each one will be progeny-tested. As the results of progeny testing come to hand, gardens yielding unimproved seed will be discarded and those showing promise will be extended. In the meantime, seed is already being distributed from the seed gardens in small quantities. Our planting recommendations for this seed remain the same. Plant three seeds per point and cull the two weaker ones.

CLONE DEVELOPMENT

(See plates 2-8.)

The vegetative propagation of desirable types is the most straightforward approach to improvement. Its possibilities are limited only by the variability of the seedling population on which it is based. Our primary object is to develop desirable types through seed, and vegetative propagation of clonal material is regarded as a means to an end, although a useful and indispensable expedient in the meantime.

This being the case and having regard to the amount of research work carried out on the subject, we determined to use cuttings rather than other forms of vegetative propagation. Satisfactory methods for the striking of cuttings and field establishment have been worked out by Mr. I. L. Edward of this Station. A paper by Mr. Edward will appear in a later issue of *The Papua and New Guinea Agricultural Journal*.

The problems associated with the use of rooted cuttings include cost, difficulty in transportation and weakness in the early stages of growth. The method of Nichols (1958) which has been tried successfully here, considerably reduces cost and goes a long way to solving the transport problem. Some years ago, stagnation of cuttings after planting out in the field was a problem of major importance, but the methods of propagation used by Mr. Edward have overcome this problem. Nevertheless, the young cutting at best is not nearly as hardy as the young seedlings and requires "nursing" in its early stages of growth.

Clone Testing

Of the 60 clones to be tested, 20 are self-compatibles and 40 are self-incompatibles. Clones are tested in series of 13 on a modified randomized block design which eliminates any possibility of fertilization of incompatible clones becoming a limiting factor in yield (see Plate 10). Nine self-incompatible clones occur in 3 x 2 plots, with a double self-compatible surround. There are four replicates and a different self-compatible clone is used as the pollen source in each of the four replicates. This has been repeated five times and a single self-compatible clone forms a bridge between all series.

In addition to testing the yielding ability of the clones involved, these trials will provide information on the influence of male parentage on flavour and cocoa butter content by comparison of the same self-incompatible clones from each replicate. Furthermore, 36 different lines of clonal seed will be produced.

Self-compatible clones not accommodated by the above trial are to be tested in a separate randomized block and will include the same bridging clone.

The first of the above series is now coming into bearing (three years old) and only the last-mentioned randomized block for self-compatible clones remains to be planted.

Field Use of Clonal Material

(see Plates 9 and 11.)

It is not proposed that clonal material be used in the form of large mono-clonal blocks. There are advantages and disadvantages in complete genetical uniformity and while uniform high-yielding ability and uniform bean characters in respect of bean size, strength and flavour and cocoa butter content are valuable, a degree of variability in other characters may be a distinct advantage.

For commercial use it is our intention to recommend the establishment of poly-clonal blocks using mixtures of 10-12 clones. In the absence of precise information on pollen movement within a block, these clones will be equally divided between self-compatible and self-incompatible clones.

In the meantime, trials have been laid down to give better information on pollen movement. These take the form of three isolated blocks—21 x 21 trees (approximately).

PLATE 2.—*Weak clone showing splitting of branch.*

PLATE 3.—*Clone testing, planted March-June, 1956. Photograph taken at three-year-old stage.*

Trial A—where the centre line of the block is planted with a self-compatible clone (KT82) with a uniform dark purple break and the surround lines are planted with a self-compatible clone (KT14) with a uniform pure white break.

Trial B—where the centre line of the block is planted with a self-compatible clone (KT14) with a uniform pure white break and the surround lines are planted with a self-compatible clone (KT82) with a uniform dark purple break.

PLATE 4.—*Upright growth with desirable, well-developed form.*

PLATE 5.—*Cutting in clone testing block, photographed at three years old.*

PLATE 6.—*Clone testing. Three-year-old trees showing profuse fan branching at base.*

PLANT 7.—*Clone testing cutting, showing three-year-old tree, demonstrating inverted clone development.*

Trial C—where the centre line of the block is planted with a self-compatible clone (KT82) with a uniform dark purple break and the surround lines are planted with a self-incompatible clone (KT8) with a uniform pure white break.

PLATE 8.—*Hedge planting of clonal material, pruning and spacing trial. Clones planted* 18 *feet by* 16 *feet in mid-*1957.

PLATE 9.—*Older clones in observation block, showing effects of pruning.*

The break of the pods set in the surrounds and setting and "break" in Trial C should enable us to trace pollen movement with reasonable accuracy. By cutting beans in the pods set on the surround trees, it will be a simple matter to determine the pollen source. Such observations will be made six months after the two clones in each block have been observed to be flowering in phase.

HYBRID SEED DEVELOPMENT

Background

Little precise information on hybrid vigour in *Theobroma cacao* has emerged but there seems to be no doubt as to its existence. The performance of ICS x SCA crosses in Trinidad reported by Bartley (1957) support this conclusion.

The nature and performance of cacao in Papua and New Guinea suggests that there is already in our population a hybrid vigour component. This is illustrated by the fact that all of our outstanding mother trees are distinctly hybrid in most characters.

PLATE 10.—*Clonal block of* 12-*foot triangle plantings in pruning and spacing trial, planted mid*-1957.

The occasional appearance in Henderson's open-pollinated progeny trials of certain weedy, abnormal progenies with a variety of genetical defects and lacking vigour led us to suspect that natural inbreeding may occur. Observations indicate that any self-compatible tree is, in fact, usually *selfed* to the extent of 50 per cent. or higher and, under these circumstances, natural inbreeding from generation to generation is almost inevitable in some small degree.

The early open-pollinated progeny trials were planted in pod rows and it is noticeable that for a particular progeny, while certain "pod-rows" are defective, others are normal (see Plate 12). It was this state of affairs which caused us in the first instance to consider the possibilities of a deliberate programme of inbreeding followed by selection and crossing of divergent types, with a view to producing uniform F_1's with maximum hybrid vigour combined with desirable agronomic characters.

PLATE 11.—*Pruning and spacing trial in clonal block. Planting* 12 *feet on triangle.*

Hybrid Programme

Generally speaking, the development of specific breeding techniques for the maximum utilization of heterosis in tree crops has been neglected. This is somewhat surprising since, although the results may take considerably longer to achieve, perpetuation may be a much simpler matter than with annual crops.

Under the circumstances, it is impossible to lay down a firm, long-range breeding programme. A tentative programme can be planned and this will require modification as preliminary results and problems

PLATE 12.—*Open-pollinated seedling cacao at* 11 *years old. Note dwarf progeny of* K10, *probably due to in-breeding The same effect has been obtained by hand pollinating* K10 *to obtain selfed seed.*

PLATE 13.—*Hand pollinated selfed progeny of* K10. *Trees are five years old.*

emerge. The period between generations, compatibility effects and the period of seed viability and other factors will require departures from the methods used for annual crops. In broad principle, however, we propose to follow the method of Comstock *et al* to make use of both general and specific combining ability.

(1) Parent trees with desirable agronomic characters have been selected within two groups (see Plates 18, 19 and 20) :—

A. Criollo or near Criollo.

B. Forastero or near Forastero.

The compatibility of all such trees has been determined.

(2) Self-compatible parent trees in Groups A and B have been self-pollinated and the S_1's planted out in a block set aside for this purpose.

(3) Further selections in Groups A and B have been made in

PLATE 14.—*Loss of vigor in* S_1 *generation. Tree is eight years old.*

PLATE 15.—*High ramifications occurring in some selfed progeny.*

PLATE 16.—F_1 *showing vigour of* F_1 *cross at approximately eight years of age.*

PLATE 18.—*Criollo-type tree.*

PLATE 17.—*Material nursery, source of cutting material for clones. Trees planted nine feet by four feet.*

the S_1's and the compatibility of these selections has been determined.

(4) Selections in the S_1's have been self-pollinated and the S_2's have been planted in a block set aside for this purpose. These S_2's are still at the seedling stage and further selections will be made in this progeny when they come into bearing.

(5) Forty-eight trees have been selected from the S_0 and S_1 generations as follows :—

Group A.—

12 Self-compatible Parents.
12 Self-incompatible Parents.

Group B.—

12 Self-compatible Parents.
12 Self-incompatible Parents.

PLATE 19.—*Criollo-type pod.*

has been planned so far. Already some interesting points have emerged from the inbreeding :

(*a*) *Vigour* (see Plates 13, 14 and 15).

S_1's show a considerable loss of vigour compared with the S_0's. No actual measurements on this have been carried out, but there is no doubt that the first generation of inbreds falls far short of the vigour of trees in our main plantings. Certain crosses were planted side by side with the S_1's and although these are in no way outstanding they are about half as big again as the selfs. Certain parent trees have thrown a highly uniform progeny indicating possibly a high level of homozygosity to begin with. Such progenies show a considerably greater loss of vigour than parents which yielded very variable S_1's indicating a high level of heterozygosity in the parent. Certain progenies (e.g., K10), and individuals within other progenies grew to a height of three to four feet and then stopped (see Plate 13). Such plants produce a profusion of chupons from the jorquette and below. These chupons expand slightly and stop growing. As would be expected the S_2 seedlings show promise of being less vigorous than the S_1's.

(6) Using the Self-incompatible selections as the female parents and the self-compatible selections as male parents, 48 crosses have been made—24 like crosses and 24 unlike crosses. Thus, this trial will provide information on the specific combining in each of 48 crosses, but little or no information will be obtained on general combining ability.

The progeny of these crosses are to be tested in a trial using a triple rectangular lattice design (Cochran and Cox, 1950) involving 12 groups of three replicates, each group consisting of four crosses (two like and two unlike). Plot size is 4 x 4 trees, 15-foot-square spacing and the whole trial is suitably guarded.

Discussion

The specific objects of the above trial are therefore—

(*a*) To test 48 specific crosses.

(*b*) To test the generalization that unlike or divergent crosses are generally superior to like crosses.

The next steps in the programme will depend on results of the programme as it

PLATE 20.—*Forastero type obtained from selfing* K4-101. *Trees are six years old.*

(*b*) *Defects*

A variety of defects has appeared in the S_1's and S_2's. These include—

Viability. There is a considerable drop in the viability of seed produced by the selfing of S_1's. This seems to be related to "embryo failure" noted below.

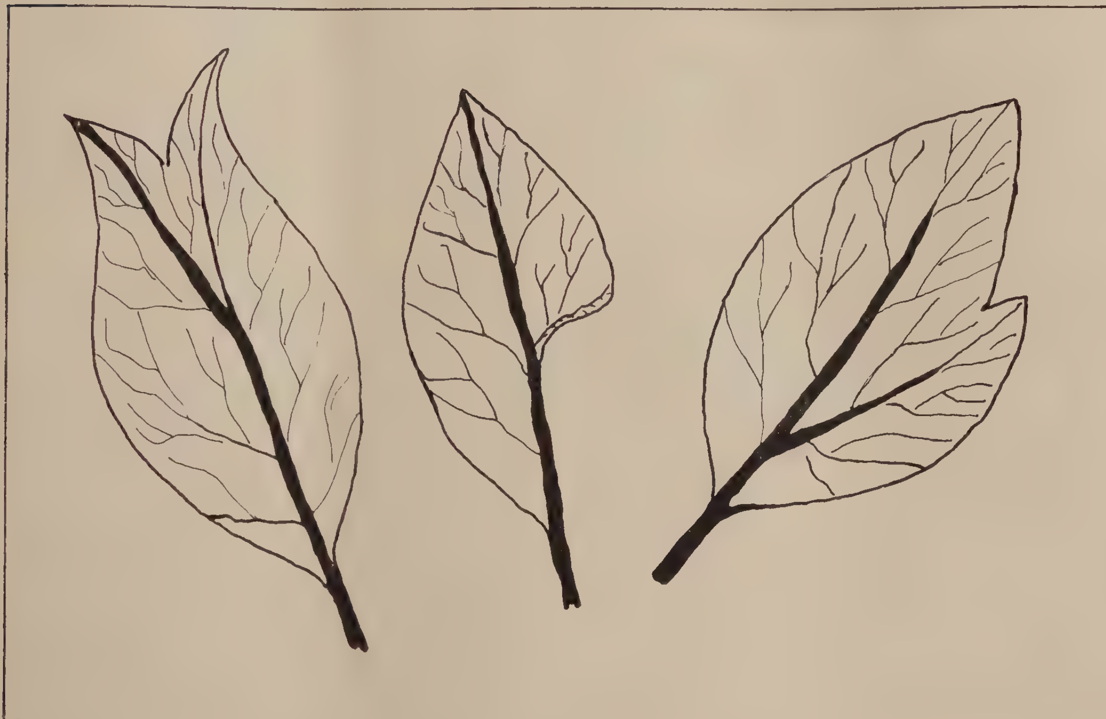


FIG. IV.—*Deformed leaves noticed on in-bred trees.*

Leaf Form. Some S_1's and many S_2's show leaf deformities in the first leaves to emerge above the cotyledons. These deformities are illustrated in Fig. IV. Seedlings appear to grow away from such deformities within the first 6-8 weeks of growth.

Cotyledon Scorch. The cotyledons of some S_1's and many S_2's show a marked scorch along the inner face. Such a bean cut across shows a brown "centre breakdown".

"*Embryo failure*". This term is used for want of a better one. The beans of certain S_1's and many S_2's often show varying degrees of incomplete development. These differ from the few undeveloped seeds which are frequently found in pods from any population. The seed appears to develop normally for some time. The testas are expanded to full size or nearly full size and, although no cytological studies have been carried out, the endosperm appears to be normal. Cotyledon growth, however, is abnormal. At one extreme there is no visible cotyledon development. In other cases the cotyledon develops to about three-quarters of normal size. In these beans the cotyledons are very loosely arranged within the testa and the viability of such beans is low. When germinated, the resultant plants are completely lacking vigour. It is noticeable that embryo failure seems to be associated with the Criollo rather than the Forastero type. The extent of embryo failure within a pod varies considerably from tree to tree. It is sometimes difficult to find a normal bean in a pod and in other cases the extent of embryo failure is slight. On trees where the selfed pods show embryo failure crossing from a divergent source causes complete disappear-

ance of embryo failure, but crossing from a close source leaves embryo failure unchanged.

Chupon Growth. Certain S_1's produce such a profusion of chupon growth from below the jorquette that this can be put in the "defective" class. The vigour of such trees is frequently normal for most inbreds.

Crazy Flowering. The selfed progeny of one parent (KA2.103) produced a great number of crazy flowerers in the ratio of eight crazy flowerers to 12 normal flowerers. KA2.103 is itself normal in flowering habit.

(*c*) *Compatibility*

The programme outlined above has involved the determination of compatibility of about 300 trees and it is at once evident that existing field methods of identification leave much to be desired. Hand pollination using the covered tube method will clearly differentiate a proportion of self-compatible clones with 12-24 pollinations. It cannot be assumed, however, that all the remainder, where "takes" have not been obtained, are self-incompatible. It has been found repeatedly that it is difficult to self-fertilize self-compatibles at certain times of the year. Following the initial separation from selfing, at the suggestion of Dr. Posnette, we therefore selfed and crossed undetermined trees at the same time, using a known self-compatible as the male parent for the cross. By doing this, it is possible to identify positively a bracket of self-incompatible trees.

This still leaves a proportion of trees unidentified—those which set neither from selfing or crossing. This group frequently includes "crazy flowerers" which carry almost no crop and whose setting ability under any circumstances is extremely poor. It also includes a number of trees carrying a normal crop which for one reason or another are not setting at the time of pollination. To identify these it is necessary to carry on selfing and crossing over a seasonal cycle.

A further group of trees which remains ill-defined, are those which, while setting readily from crossing, set only occasionally from selfing. It would seem, therefore, that the method of identification of compatibility developed by Cope (1939) based on cytological studies would give much quicker and surer results.

The most significant incidental finding arising from compatibility determinations on some 200 S_1 trees is that in no case has it been possible to demonstrate self-incompatibility. In all cases, S_1 trees which could not be selfed also could not be crossed with a self-compatible. Compatibility determinations on the progeny of self-compatible x self-incompatible crosses, identified both self-compatibles and self-incompatibles. Insufficient trees were tested to determine segregation. From this it can be concluded that, for compatibility to occur in our cacao population, the factor must be present as a homozygote and it is recessive. This is in accordance with Cope's (1957) finding, but insufficient evidence is available to confirm or discount the three loci postulated by him.

Importance of Compatibility to the Hybrid Programme

The inheritance of compatibility is a matter of signal importance in our hybrid programme, because of the usefulness of self-incompatibility in the production of hybrid seed in commercial quantities. Future steps in the programme, therefore, depend largely on this question.

In producing hybrid seed in commercial quantities, the simplest method will be to pair a self-compatible parent with a self-incompatible parent in a large, isolated seed garden where pods harvested from the self-incompatible will yield the cross. This factor has been a major determinant in the crossing programme described above. Owing to the absence of incompatibility among the inbreds, it has been possible to draw only male parents from this population and female parents (self-incompatibles) have been largely drawn from the S_0 generation.

This limitation could be removed if a method could be found for distinguishing the pods resulting from selfing and from those resulting from the crossing of two self-compatible parents. Similarly, the problem would be solved if a method could be devised enabling us successfully to self-fertilize self-incompatible trees.

However, in the event of neither of these alternatives being possible, it would seem that our only other alternative will be to cross the inbreds in Group A with a Criollo-type self-incompatible from the S_0's and cross the inbreds from Group B with a Forastero-type self-incom-

patible from the S_0's to reintroduce self-incompatibility to the inbreds. The choice of parent trees in the S_0's for these crosses will be a critical matter and full attention will have to be paid to their general combining ability. The results of Henderson's open-pollinated progeny trials give a rough indication of the general combining ability of a wide group of S_0 parents.

Subsequently, divergent crosses between Group A and Group B can be made, again choosing self-compatibles and self-incompatibles from each group. Such crossing would resemble the double cross method. In the programme of crossing described above, such crosses are included and we may well have to use the progeny of such crosses to carry on the programme.

SUMMARY

The origin of cacao in Papua and New Guinea is described. This cacao population falls within the "Trinitario" complex. The scope for possible improvement as indicated by the range of variation within the cacao population is discussed. The objects, problems and methods of cacao improvement as used at Keravat are described. The bases for selection in a variable cacao population and the actual selection programme at Keravat are briefly reviewed. Particular attention is drawn to the potential importance of competition effects when selecting for yielding ability. The necessity for satisfying the requirements of both growers and manufacturers is emphasized.

A programme for the production of clonal seed is summarized. The use of the term "clonal seed" in this paper means seed derived from the crossing of two clones. Trials designed to throw light on normal pollen movement within a block of cacao are described.

The development of clones for commercial use and the method of testing at Keravat are given. The possible direct effects of male parentage on bean quality and the difficulties introduced by self-incompatibility in designing clone-testing trials are discussed.

A programme for the development of uniform hybrids through seed is described. This involves the inbreeding of divergent lines followed by selection, out-crossing and progeny testing. The problem of producing hybrid seed in commercial quantities is discussed. Problems introduced by the inheritance of factors for self-compatibility are described. Field trials associated with this programme are designed to test 48 specific crosses and to test the generalization that divergent crosses are likely to give superior results to close crosses. The effects of inbreeding to mature S_1's and to S_2 seedlings are recorded. These effects consist largely of loss of vigour and the appearance of various defects. Mention is made of possible future trends in this programme.

ACKNOWLEDGEMENTS

The foundations of the above improvement programme were laid by Mr. F. C. Henderson, the present Director of Agriculture, Stock and Fisheries, from 1946 to 1952. Without this foundation the present programme would have been impossible. The assistance of Mr. A. E. Charles and Mr. P. N. Byrne, of this Station, who have carried out much of the work in relation to our breeding programme and who have greatly assisted in compiling this report, is gratefully acknowledged.

The designs of all field trials have been worked out in conjunction with Mr. G. A. McIntyre, Biometrician, Division of Mathematical Statistics, C.S.I.R.O., Canberra. We are indebted to Mr. McIntyre for his invaluable assistance.

REFERENCES.

BARTLEY, B. G. D. 1957. Trinitario scavina hybrids—New prospects for cacao improvement. Report of C.C. and F.A. Conference.

COCHRAN, W. and GERTRUDE M. COX. 1950. Experimental designs (N. G. Wiley and Sons, London). Section 10.10, p. 295.

COMSTOCK, ROBINSON and HARVEY. A breeding procedure designed to make maximum use of both general and specific combining ability. U.S. Dept. Ag. Journ. Paper 307.

COPE, F. W. 1939. Studies in the mechanism of self-incompatibility in cacao—11. Ninth annual report on cacao research, I.C.T.A., Trinidad.

COPE, F. W. 1957. Cacao research—incompatibility. Report of governing body and principal's report, I.C.T.A., Trinidad.

GREEN, E. C. D. 1938. Cacao cultivation and its application to the Mandated Territory of New Guinea. N.G. Agric. Gazette 4 : 4.

HENDERSON, F. C. 1951. Expansion of cocoa growing in Papua and New Guinea. C.C. and C.A. Ltd., Cocoa Conference report.

NICHOLS, R. 1958. Propagation of cacao in plastic bags. Nature 181 : 4608, p. 580.

PLATE 1.—*A Robusta coffee nursery being weeded.*

ROBUSTA COFFEE IN SOUTH-EAST PAPUA

K. S. COLE.

The author, until recently District Agricultural Officer at Samarai, in this paper describes the cultivation of robusta coffee as a guide to European planters. Mr. Cole points out the firm nature of the market for robusta which exists in Australia, then outlines the procedures for establishing the plantation, including clearing, establishment of shade, nursery practice, transplanting and maintenance. He stresses the need for care in processing the coffee and emphasizes that faulty processing may spoil a high-grade bean.

THIS article is primarily intended for owner-planters in the Milne Bay district who are beginning to plant robusta coffee (*Coffea robusta,* a variety of *Coffea canephora*). Most of the findings discussed in this paper will also apply to other areas, but it is emphasized that they are the result of trial, observation and experiment carried out by officers of the Department of Agriculture, Stock and Fisheries stationed at Samarai.

Robusta coffee is not regarded as highly on the world's markets as its Highland cousin, arabica (*C. arabica*) but it enjoys a firm share of the Australian market, which is expanding. The darker and sharper-flavoured robusta is used mainly in soluble coffee extracts, for espresso-type coffees and in many of the cheaper blends, or mixed with chicory.

The lower return for robusta coffee is partly offset by other factors—good yields and cheaper access to shipping points than in the Highlands—but the successful robusta planter must ensure that his return is maintained by efficiency of production.

This article should be read in conjunction with an earlier publication on arabica coffee (J. W. Barrie's "Coffee in the Highlands of Papua and New Guinea", *P.N.G. Agricultural Journal, Vol.*

11, *No.* 1) as many of the procedures are very similar to those used with the Highlands crop.

As the name implies, robusta coffee is a vigorous tree. If left to its own devices it will quickly grow into a tree more than 20 feet high and produce masses of suckers and laterals. Its leaves are large and glossy and the tree has a handsome appearance. There is a considerable variation in size, shape and vigor in the robusta coffee in Papua and New Guinea. This variation seems of little importance, though extreme types should be rogued out. Robusta may be differentiated from arabica by greater vigour, larger leaves and smaller beans. It may also be differentiated from liberica (*C. liberica*) which has very large leaves, is extremely vigorous, has very large cherries and is much slower to reach bearing. Liberica coffee is of little value.

The robusta coffee growing in the Milne Bay district was derived from two sources. In early experiments, seed was obtained from Popondetta but this was discontinued when it was noted that there was a great variation in tree type and later in bean size. All later introductions of seed came from the Lowlands Agricultural Experiment Station at Keravat, near Rabaul. This has resulted in a much more even line of trees, although variations are still present. A certain amount of variation is necessary as robusta coffee is to a large extent cross-pollinated and in most cases is self-incompatible. Therefore, it is essential when choosing mother trees for seed to select six or eight trees and to mix up the progeny of these trees as much as possible to ensure good fruit set. Similarly, if seed is purchased from native growers it should be obtained from two or three growers and bulked before planting in the nursery.

It is proposed to discuss the culture of robusta coffee under the following headings :—

1. Soils and climate.
2. Land preparation, nursery establishment and plantation management.
3. Pests and diseases.
4. Harvesting and processing.

SOILS AND CLIMATE

In the Milne Bay district, robusta coffee does well on a variety of soils and under a variety of climatic conditions. The best soils appear to be the acid, deep, well-drained, friable loams along the rivers and creeks or at the base of the ranges. Even so, the silty gravels and gravelly loams of the D'Entrecasteaux Islands support thriving coffee gardens.

Robusta coffee appears to grow best at altitudes up to 1,500 feet, although some very healthy gardens occur in the Mullins Harbour area at 1,700 feet or more. However, growth rates appear slower under these conditions. Along the coast on suitable soils growth is vigorous and trees fruit heavily.

A most important factor is the available rainfall. Coffee does not flourish unless the rainfall exceeds 75 to 80 inches and is well distributed during the year. An even higher rainfall is preferred. Marked seasonal rainfalls as on the North-East Coast-Cape Vogel area and Goodenough Island are not suited to robusta culture. Similarly, heavy clays, laterites, ironstone gravels, Kunai country, calcareous soils, steep slopes and shallow soils do not favour successful robusta coffee growth in this area. Robusta will put up with periods of drought of two to three months but if the drought continues growth ceases and the plants droop and may drop the fruit.

Periods of heavy consistent rain, which occurs in Milne Bay and the Sagarai Valley in particular, appear to do no harm. Recently, coffee trees in the Sagarai area were inspected after they had been subjected to 12 weeks' almost continuous rain. The trees were healthy and vigorous despite the lack of sunshine, although the soil was almost liquid mud. These trees were often standing in water for several days at a time, but appeared to have suffered no harm. Even where rainfall often exceeds 150 inches a year, the robusta flourishes, provided ground water does not become stagnant and free drainage of excess water can occur when the rain stops.

LAND PREPARATION AND NURSERY ESTABLISHMENT

Clearing, lining and holing

The best land for coffee culture is that which has been under forest cover for several years. Successful plantations have been established on old garden areas, but the built-up fertility of forest land gives the coffee trees a good start and the lack of weed infestation is an advantage.

Trees should be felled during the latter stages of the south-east wet and allowed to dry. With the onset of the doldrums in October-November

a good burn should be obtained, and, after picking up, the land should be relatively clear for pegging of lines and holing. Usually, it is unnecessary to grub the stumps for coffee as most of the stumps are softwood and soon rot out. Except for primary forest land or on land which has been under regrowth for many years there will be very few hardwood stumps to worry about. A good burn is rarely obtained in the April-May doldrums and if the forest is cut too early in the wet the regrowth is so vigorous that a second clearing is needed, or a very poor burn will be obtained.

Once cleared, the pegging of the land can be carried out. A large number of sharpened stakes about six feet long and about an inch in crown diameter will be required. Approximately 500 trees are planted per acre and each tree will be represented by a peg.

Pegging or lining may be on either the triangle or square, to give tree distances of at least 10 feet. The triangle is preferred as it gives about 13 per cent. more trees per acre. A non-stretchable wire may be used for pegging but we have found two poles just as effective, once a good base line is established. Boys do not lose the sticks or break them as easily as they do with wire.

The technique used is to peg out a straight base line at 10-foot intervals. This base line should, if possible, be parallel to the direction of the main prevailing wind. This will vary somewhat due to peculiarities in local relief. Once the base line is established, two sticks exactly 10 feet long are needed for further pegging. By placing one end of a stick against a base line peg and an end of the other stick against an adjacent peg and bringing the two free ends together an equilateral triangle is formed. The point where the two sticks meet is pegged as the position of a tree. A move is now made along the base line to position further pegs. The ends of rows can be cornered out by a slight manipulation of the sticks. It has been found that native labourers become proficient at this form of pegging after a few minutes' instruction. A minimum of four labourers is required though five work much faster. The only points to be careful about are :—

PLATE 2.—*Marking out exercise for native Robusta coffee.*

1. The base line must be straight and accurately pegged for intervals.
2. The sticks must be accurate for length.
3. The sticks must be accurately placed against the pegs and the ends must meet cleanly.

In pegging, near enough is not good enough. A small error is carried on and multiplies as pegging continues. If a space is left for a roadway it is advisable to peg a new base line rather than attempt to carry the old line across the road. By pegging a new base line, any errors in the previous area are discarded in the new block. After pegging, a quick look along the line and along the diagonals will reveal errors in pegging.

Once the land is pegged, holing and planting of shade may be started.

Well-prepared holes give the young coffee tree a very good start. If the planter has been overambitious and has cleared and pegged too great an area for his labour to handle, he would do better to abandon an area temporarily rather than skimp on holes and shade.

In this district it has been found that holes which measure two feet by two feet give very good results. Small holes lead to root restriction and slower growth. Larger holes are no doubt better, but are more expensive to dig.

The holes should be dug as soon as possible before planting and left open to the weather. During the digging, the topsoil and subsoil are separated by placing on opposite sides of the hole and not in the row. Approximately one month before planting out the coffee, the holes should be filled with topsoil only. All stones are discarded and the replaced soils are mounded over the hole. Just before filling the hole it is as well to stir up the soil in the base of the hole as this may cake if much heavy rain has occurred. The replaced soil will tend to settle and if this is excessive more soil should be added to the mound.

Shade Establishment

Under the conditions prevailing in the Milne Bay district, robusta coffee will not grow without shade. A total lack of shade, even in very cloudy areas such as the Sagarai Valley, results in stunted plants, yellowing and sunburning of the leaves, defoliation and even death of the plant. Insufficient shade results in yellow leaves, sunburning and retarded growth. Where shade is adequate the trees are a healthy colour, grow well and begin bearing about two years after planting out.

Both temporary and permanent shade should be planted as soon as possible after lining and holing. If planted at the beginning of the north-west wet it will be well grown by the beginning of the south-east wet and coffee planting can proceed in the most favourable season. Well-grown and vigorous shade will also help to control any weed problems.

Permanent Shade Tree

The best shade tree for robusta coffee is *Leucaena glauca*. It is advisable to inoculate *Leucaena* seed before planting and it will be found that, once established, growth will be rapid and a good cover obtained. The main drawback is the large number of seedlings which come up. Provided the original trees are well grown, these seedlings are suppressed and can be dealt with, but if neglected, or if the original shade or cover is weak, a veritable jungle can occur.

It has been found that the best planting distance for *Leucaena* is 10 feet apart, initially. As the shade trees grow they can be thinned out considerably and still provide adequate shade cover. It must be remembered that it is easy to establish shade before the coffee is planted and it can always be removed if too heavy, but it is extremely difficult to establish shade in mature coffee if the original shade cover was too light. An excess of shade in the early life of a plantation is a good fault. It must be remembered that coffee planted with inadequate shade will be set back and may be a total loss. Therefore, no attempt should be made to plant coffee until the shade is right.

There are two techniques for planting shade trees :—

1. Planting seed at stake.
2. Planting rooted seedlings or cuttings.

With seed, a small area of soil midway between two pegs is stirred up with a knife point and a slight depression made. Four or five inoculated seeds are dropped into the depression and about a quarter to half an inch of soil is gently pushed over them. Germination will occur in four or five days if conditions are favourable, and provided weeds are controlled satisfactory shade will be established.

The second method is, however, recommended as being the better one. The *Leucaena* is raised in a nursery bed using inoculated seed and when three or four feet high the seedlings are pulled up or trenched out. The seedling is trimmed by cutting off the top nine inches or so and all lateral branches and leaves. About four or five inches of tap-root is left and all lateral roots are trimmed off. The seedling, or whip as it now is, is planted out by making a hole with a crowbar or pointed stick and pushing the tap-root down into the soil at the bottom of the hole. The hole is filled in by breaking soil off the sides of the hole. Using this method in moist soil or during rainy weather, we have had very few whips fail to take. One whip should be planted midway between two coffee pegs and further whips about six inches on either side of the central one. The whips usually shoot in about 10 days and if planted in suitable soils in January or February will be 10 to 12 feet high by June-July and will be providing a good cover within less than a year.

The nursery for the *Leucaena* seedlings should be established where it can be watered and where the soil is easily worked. A bed about four feet wide is dug up and the soil broken down to a reasonably fine tilth. The actual length of the bed will depend on the convenience of the individual planter. It is important to eliminate all weeds as they will grow faster than the *Leucaena* in the early stages and may suppress or kill it. Rows are marked out about nine inches apart, leaving a pathway in the centre of the bed. Seeds are inoculated and distributed along the rows. From eight to ten seeds per foot are sufficient as more will result in very spindly seedlings and less will cause excessive lateral branching. In three to four months, depending on weather, the seedlings will be ready for transplanting.

The method used to get the seedlings out of the ground will depend on personal preference. Good labour will pull from 500 to 1,000 or more seedlings in a day but poor labour or untrained labour will pull only 200 to 300 seedlings in a day and will end the day with blistered and skinned hands. If difficulty is being encountered it is far better to trench out the seedlings, especially if they are very well grown.

Temporary Shade

Once the permanent shade has been planted out, the temporary shade may be planted. It is not absolutely necessary to plant temporary shade, but it has the following advantages :—

1. It enables the coffee to be planted out sooner.
2. It forces the *Leucaena* to grow up rather than out.
3. It helps to suppress weed growth.

The best temporary shade for the district is *Crotalaria anagyroides*. It grows rapidly and seeds freely and will last up to 18 months, although it is not needed after the first year. In its later life it becomes defoliated and straggly and serves no useful purpose. It is also susceptible to rust disease, leaf virus and pink disease, but these rarely cause much trouble in the first nine to 12 months of growth, by which time the plant has served its purpose. The *Crotalaria* plants may be removed by slashing with a knife and can be stacked between the rows. In a few months the plant will have completely rotted away. The stumps of the slashed plants rarely recover and the root system will also rot away quickly.

It has been found that the *Crotalaria* need not be planted as thickly as in the Highlands. The seed is planted in the coffee row and, starting about six inches from the edge of the hole, a small area of soil is broken up and three or four seeds dropped into the soil and covered. Further seeds are planted at about 12-inch intervals along the row and so on until the space between two pegs has been filled in. Germination will occur in a few days and growth will be rapid, provided the soil is moist and early weed competition is eliminated. This method does not use much seed, but provides sufficient temporary shade. Shade control can be achieved by partially slashing back the *Crotalaria,* should it become too heavy or overhang too much.

Nursery Establishment

This is one of the most important steps in ensuring a successful plantation. If the coffee seed or seedlings are not good it is impossible to obtain good producing trees.

The seed may be obtained from the Department of Agriculture, Stock and Fisheries or from native growers in Milne Bay. If obtained from native growers, then two or three growers should be chosen and the seed bulked. It is advisable to select healthy, vigorous, heavy-bearing trees

with fruit which is uniform in size, then no trouble will be experienced in processing the eventual crop.

Those who are interested in selecting their own seed or buying native-produced seed are advised to read the section on seed selection in *Coffee in the Highlands* (Barrie, 1956).

Coffee seed should be planted out as soon as possible as it does not keep well. To save time and effort, it is advisable to plant the seed in a germinator bed first, and while the seed is germinating—it takes from four to six weeks—the nursery beds may be prepared. A suitable germinator need be only a few square feet in area but it must be well shaded and near a water supply.

An area of loamy soil is dug and a fine tilth obtained. The seed is placed flat side down in rows on the surface and covered with a layer of Kunai grass or a bag and well watered. The seed must be kept damp and shade must be provided or germination will be most erratic. From about the third week frequent inspection should be made for signs of germination. As soon as the seeds germinate they should be transferred to the main nursery beds. It is not necessary to wait until leaves appear before removing the seed to the beds. If removed as soon as the radicle appears there is no danger of bench-rooting, but if left till bigger the seed is easier to handle. Some growers prefer to move the seed as the radicle appears and before it achieves any length.

The main nursery bed should be sited near a water supply and as near to the planting area as possible. Good soil is essential if the seedlings are to grow well. The beds should be about five feet wide, as long as convenient and be well dug to remove weeds, roots and stones. The ground should be mounded up to provide good drainage. The application of a good mixed fertilizer may be helpful in some circumstances.

A shade shelter must be built over the nursery bed and should be high enough to allow labourers to move underneath it to weed the seedlings. A five-foot-wide bed should allow for four lines of seedlings and a pathway between the two inside rows of seedlings.

The seedlings should be planted nine inches apart in the row and the rows should be nine inches apart. Initially, the shade should be heavy but it can be reduced as the seedlings grow. Plaited coconut fronds provide suitable shade in the early stages and later green coconut fronds are suitable as they automatically reduce the shade supplied as the fronds dry out.

PLATE 3.—*Shade opened up to allow light through to Robusta coffee seedlings.*

The actual length of time in the nursery depends on when the seed was obtained and also on personal preference. In Milne Bay, most coffee ripens in June and July and so seed must be collected then, but seed is available from other areas much later in the year, even December. It has been found that coffee transplanted in June or July makes much better growth than coffee transplanted in September or even during the north-west monsoon. Therefore, seedlings can be from six to 18 months old when transplanted. If care is taken with the transplanting, good results can be obtained with seedlings six months old, or even younger. When the seedlings are older they are easier to handle and recovery is quicker from transplanting.

Irrespective of when the seedlings are transplanted, care must be taken to avoid benched tap-roots. Benched tap-roots are caused when

tap-roots are bent during transplanting and will result in a weak and unprofitable tree. When older seedlings are being used, the use of root pruning eliminates bench rooting, but with younger seedlings the tap-root should be pruned when the seedling is dug up.

Root pruning of older seedlings is carried out in the nursery about six weeks before transplanting. A spade is pushed into the soil about four inches away from the base of the seedling. The handle of the spade is tilted down and the end of the blade severs the tap-root with a distinct snapping sound. The plant is firmed down in the soil and left until needed. The young plant responds with a mass of new root growth which binds together a ball of soil around the root system. Transplanting is thus facilitated as the plant may be moved with the ball of soil and is not set back very much.

When younger plants are used, the tap-root must be cut off after lifting. A sharp knife or secateur is needed and the root should be pruned well back. The temporary setback of heavy root pruning is a small price to pay for a healthy plantation later on. The remaining tap-root should be fairly rigid and should not bend easily and so cause bench rooting.

Transplanting

The holes for the young seedlings should have been filled about a month before transplanting and probably the most important step in developing a coffee plantation is about to take place.

If the planting is poor, a poor plantation will result. The planter should take note of the following points :—

1. Try to transplant during wet or dull weather. If the weather is sunny then transplant late in the day and water the seedlings.
2. Use only strong, vigorous seedlings.
3. Do not dig up more seedlings than you can transplant in a day.
4. If roots are not protected by a ball of soil, quickly cover with a wet bag to prevent drying out.
5. Do not waste time between digging up seedlings in the nursery and setting them out in the field.
6. Do not plant too deeply. The young tree should be planted out at the same depth as it was in the nursery. If planted too deeply, the lateral root system will not develop and the plants will be weak. Coffee is a surface feeder and must have lateral roots for this purpose.
7. Make sure seedlings are root pruned before transplanting.

If the above points are noted there should be no trouble in establishing the coffee trees successfully.

Pruning

This very important aspect of coffee culture must be included in plantation practice. Failure to prune trees properly will result in a loss of yield, or force trees into biennial bearing. The trees may also become too tall to work and grow a mass of suckers.

A number of systems of coffee pruning have been tried in Milne Bay and the Agobodia or "Arch pruning" method has been adopted as the most suitable.

The young seedling is allowed to reach waist height (say 3 feet 6 inches) before pruning. At the appropriate time the laterals on one side are removed and the tip cut off. The seedling is now bent in the direction of the row and fixed in the form of an arch by pegging with a hooked stick. Any laterals on the upper side of the arch, which would interfere with the growth of vertical shoots, are removed. In very wet weather, when the soil is soggy, it is also advisable to hold the base of the trunk with one hand when pulling over the tree because seedlings have been almost pulled up in the process of bending.

In a short time, vertical shoots will develop along the stem. It is usual to select four or five of these shoots as the future tree. The selected shoots should be evenly spaced and vigorous and as far apart as possible. These uprights will grow quickly and develop laterals and the original arch will become set. The end of the arch, which bears no uprights, may now be removed.

It should be borne in mind that the tree should be arched in the direction of the row. If this is done there will be no impediment to movement down the row and no resistance will be offered to the prevailing winds.

PLATE 4.—*Arch pruning of Robusta coffee.*

As the verticals age and become denuded of laterals, or grow too tall, they are pruned and new ones are allowed to grow. The laterals carry the fruit and eventually the lower ones become exhausted and must be removed. This results in a tree which is spindly and has a heavy top hamper. It will be noted that suckers develop from the base of the verticals and one sucker should be selected to replace a vertical which is removed. It is possible by this method to rework a tree and still keep it in bearing.

If trees are overcropping it will be necessary to prune back some of the laterals or remove excess cherries. This operation is best carried out early in the fruiting cycle before the trees are affected by the excessive crop. Trees which overbear will be poor bearers later on and may develop biennial bearing. With young trees it is best to limit the crop until the tree is fully mature.

When to Prune

The best time to prune is open to question. The original pruning to develop the arch may be done when the tree is sufficiently developed. Overseas authorities claim the best time to prune is when harvesting has been completed. The tree is then semi-dormant as the crop has ripened during the dry. However, in the Milne Bay area, ripening occurs during the wet and the tree does not appear to have a dormant period. Flowering does not usually occur until September, so there is a period when the tree has no fruit on it and pruning can take place during this period.

Generally, with arch pruning, apart from the replacement of worked-out verticals and the removal of exhausted laterals and excess suckers, there appears to be little required in the way of pruning. Heavy pruning will result in lower yields and may force excessive leaf growth at the expense of flowering. Therefore, it is

recommended that prunings be kept as light as possible. However, it is essential to remove all excess sucker growth at all times or the tree becomes unworkable.

Mulching

As the coffee tree is a surface feeder, it consequently has a large proportion of the root system in the surface soil. To protect this root system from drought and excessive temperature it is advisable to mulch the ground. It must also be remembered that mulching helps to return nutrients to the soil and maintains soil texture.

In view of African work on mulching, it would appear that complete mulching is not advisable in this area except in the lower rainfall areas. Alternate row mulching would tend to be indicated in wetter areas. It has been found that lack of mulching has no serious early effects, although soil depletion may occur in the long run if no mulching is carried out.

Unfortunately, there are no large areas of grassland to our main coffee areas. Elsewhere it has been found that *Themeda* spp (Giant Kangaroo grass) is most suitable, while *Imperata* spp (Kunai) is most useful. Unfortunately, neither of these grasses is available in the quantities needed, although Kunai is often freely available on coconut plantations.

Pennisetum purpureum (Elephant Grass) has been recommended. It has been found to yield a big bulk of mulch, but unless dried out very well it rapidly takes root from the stalks and takes over the plantation. Once established it is troublesome to eradicate and adversely affects the trees. If it can be dried out properly, then it is most useful as a mulch. This grass stands cutting well and yields a large bulk of green material per year.

Cover Crops

These are not recommended as they compete with the coffee plants for soil nutrients and appear to have an adverse effect on the coffee trees.

Weed Control

This aspect of plantation management cannot be neglected if coffee is to yield well. Weeds compete actively with the shallow-rooted coffee tree and yields fall off very quickly. The worst offenders are the grasses, such as Kunai, which not only lower yields but may even limit vegetative growth.

Proper shade, mulching and hand weeding are all useful and will keep the weeds within bounds. Constant attention will be required, for if the weeds get away it will take months for the trees to recover. The exception seems to be *Leucaena* seedlings which appear to do little harm if prevented from growing too big.

It should be kept in mind that weeds are also a harbour for pests and diseases. A tree weakened by competition is much more readily attacked and suffers much more heavily than a healthy, vigorous tree. The weeding line should be active all the time and an area needs to be weeded about every six weeks.

Pests and Diseases

So far no really serious pests or diseases have occurred in the Milne Bay district. The main pests attacking coffee are :—

1. *Coffee stem borer*

This moth bores into stems and on reaching the heart wood begins to tunnel towards the tip of the affected branch. The branch wilts and then dies or may snap off at the point of entry. Attack may occur on any part of the tree, although usually a point several feet above ground level is attacked. If a vertical branch is attacked then there is a serious setback to yield from that branch. At present there is no economical method of control but as yet damage is not serious.

2. *Mealy bugs*

A number of reports has been received of mealy bugs and their attendant ants infesting the fruit clusters. On occasion the young fruit may die from the attack. Control may sometimes be obtained by spraying with white oil at one per cent. No serious infestations have been reported.

3. *Scale Insects*

The only scale insects noted to date are a green scale and a brown scale. Neither is serious and they occur only on trees which have been weakened by excess weed growth or insufficient shade, or both. Healthy trees do not appear to be affected by these insects.

4. *Thread Blight* (*Pellicularia koleroga*)

At one period it appeared as though this disease would seriously hinder growth of coffee in the Milne Bay area. Diseased trees were defoliated and some laterals and diseased growing

tips were killed. It has been noted that clean coffee gardens are not badly affected, especially where there is a free flow of air through the plantation. Humid conditions, weakened trees and restricted airflow produce conditions favourable to the disease. Where trees are infested, dead foliage and branches bearing the threads (which may be found on the underside of the laterals) should be removed and burned and ventilation of the plantation should be increased.

5. *Root Rots* (*Fomes* spp)

Root Rots are mainly of the white type. They are not serious and account for only a few trees. The diseased tree dies. It has been found that tracing the affected roots and removing them eliminates the trouble. A trench is dug around the diseased tree and by working into the centre of the area roots are found and can be removed for burning. Provided all such material is removed and the soil replaced with soil from a non-infected area, a new tree can be planted in the position almost immediately.

At present there do not appear to be any other pests or diseases of consequence.

HARVESTING AND PROCESSING

The end result of all work in the plantation depends on these two stages. Lack of care and attention can spoil the final product, no matter how good the cherries are. It is impossible to improve poor cherries, but it is possible to spoil a good product. Only fully-ripe cherries should be harvested to ensure a high-grade product. If immature or over-ripe cherries are used, then an inferior product will result. Unfortunately, not all cherries in a cluster ripen together and if supervision is not good a mixed sample will be turned in by the pickers. It is difficult to give a colour classification for ripe cherries in this district. As the cherries ripen during the wet south-east season, there is little sunshine to colour the cherries. It has been found in the Sagarai Valley that the cherries turn yellow and have only streaks of pink colouring. Rarely does one see a well-coloured cherry under these conditions of heavy rain and dull, overcast skies. In Milne Bay, the cherries are usually coloured pink but rarely achieve a good deep red colour. In the D'Entrecasteaux Islands to date the cherries usually colour well.

The producer may well wonder how to decide when to commence picking. A good guide is to pick a few cherries and press gently between thumb and forefinger. If ripe, the skin will split and the beans will be ejected easily. If a fair degree of pressure is needed to cause pulping, then the cherries are not ripe. Labour can be taught in a few minutes to select ripe cherries using this method.

The main picking season is May to August with June-July as the heaviest months. There will be some picking throughout the year, but mostly it will be of little consequence to the income of the plantation.

At present there are no accurate yield figures available. Trees in this area have completed two years in heavy bearing, show no signs of exhaustion or die-back and are heavily budded for the next flowering. As yet it is too early to say what ultimate yields will be, but at present they are heavy enough to be profitable and are increasing each year. Overseas authorities refer to yields in the order of 1,500 lb. of clean dry beans per acre. It is possible that these yields will be matched and even surpassed on the good silty loams in the better rainfall areas of the district.

Once harvested, the cherries should be transported quickly to the factory and processing should be commenced immediately. If the cherries are allowed to remain unpulped for too long, fermentation may take place in the heap. This can cause off flavours, discolouration and odours. All these are detrimental to the production of good-quality coffee beans.

The plantation owner is advised to have the morning pick pulped and placed in a fermenting vat as soon as possible after the midday break. The afternoon pick is then pulped and placed in a separate vat. Although this may double the number of vats in use, it is preferable to storing the cherries until late afternoon, with a consequent risk of a poor-quality sample.

The extra outlay in vats will be recouped by producing a superior product.

The bulked cherries should be dumped into a washing vat full of water and slightly agitated. Unripe and over-ripe cherries will float to the surface and may be skimmed off and treated separately as they produce an inferior grade of coffee. The ripe beans should be taken from the bottom of the vat and pulped before passing to the fermenting boxes.

The efficient working of the pulper will do much towards turning out a first-class product. It is necessary to have a good supply of clean water running through the pulper when the cherries are going through. If the pulper is adjusted too tightly, then many beans will be nicked or broken. Beans which have been nicked or broken will show stains from fermentation and may develop off flavours. If the pulper is too loose, many cherries will not have the skin and pulp removed or, worse still, they will be ejected with the waste and lost.

No matter how carefully the pulper is adjusted some pulp and unpulped beans will pass into the fermenters. In a well-organized factory this material is passed to a repulper. Much can be done to minimize this factor in robusta coffee. Normally the robusta coffee in this area is rather uneven in bean size and sometimes it is possible to pick the smaller cherries on different days from the larger ones.

The use of a grader to separate the cherries into more even sizes or grades is also to be recommended, especially when there is any great variation in cherry size.

The pulped beans are transferred to the fermenting vat. This vat may be constructed of timber or of concrete. On a small scale, very good results have been obtained by using hollowed-out logs, similar to native canoes in appearance. The beans, if only a small batch, are just covered with water and agitated, then left to ferment for about 24 hours. Overseas authorities recommend that, when larger quantities are fermented, the water should be drained away and two feet or more in depth of pulped beans be left in the vat to ferment. Fermentation is complete when a handful of washed beans from the fermenting tank has a gritty feel when rubbed. If the beans are still slippery, then fermentation should continue.

Once fermentation has finished, washing should be carried out. If washing is delayed, then off flavours will be developed, due to over-fermentation. If washed before fermentation is complete, further fermentation will take place on the drying trays and cause off flavours. However, over-fermentation is the more serious fault.

Plenty of clean water is required for washing the beans. It is not possible to overwash the beans, but underwashing can lead to an inferior product. Several washings are given before the beans are drained and put out to dry.

As the coffee harvesting season coincides with the wet south-east winds, drying problems are to be expected. The plantation owner is strongly advised to install mechanical drying if possible. During very wet periods, it is extremely difficult to reduce the moisture content of the wet beans to the required 11 to 13 per cent. A useful test of dryness is to bite the bean. If the beans give to the bite, they are not dry enough.

If sun drying is to be used, then a drying period of nine days or more will be required. It has been found preferable to use trays which are portable and which can be supported on a raised platform. If the drying beans are allowed to come in contact with the ground, they may absorb off odours. The drying beans must be protected from rain or other sources of wetting if a discoloured product is to be avoided. It is important not to overcrowd the beans on the tray and a depth of no more than one inch should be allowed. During drying the beans should be frequently stirred to allow even drying.

When mechanical drying is used, much time is saved, but greater care must be exercised. Overseas authorities recommend an initial temperature of 80 to 85 degrees C. (176 degrees F. to 185 degrees F.) and after six hours the temperature is reduced to 75 degrees C. (167 degrees F.). Other authorities recommend lower temperatures and slower drying.

The dry coffee must be allowed to cool before bagging or storing. It should not be stored for long periods as it deteriorates and takes up moisture under conditions of heat and high humidity. Similarly it should not be stored on concrete floors but on wooden platforms raised off the floor. If stored for any length of time, or if the weather has been particularly humid, it is advisable to give the coffee a partial re-drying before attempting to hull the beans. It has been found that placing on trays in the sun for a day is usually enough to bring the coffee to the required degree of dryness for effective hulling. If hulled when insufficiently dried, many of the beans will be squashed or broken.

The hulling of the coffee consists of removing the outer skin or parchment and the inner or silver skin. Normally these skins are removed by machines and a polish imparted to the bean at the same time. There is a number of machines on the market for performing these tasks and the choice appears to be one of personal preference.

Following the hulling and polishing it is advisable to grade the beans into an even sample. Mechanical grading also helps to remove any trace of silver skin which has remained on the beans. Robusta coffee has a tight, silver skin, which often adheres fairly strongly to the bean, particularly if the bean is not completely dry. The jostling and bumping in a rotary grader does much to remove these traces. It must also be kept in mind that an even, well-graded sample is much better received in the trade. The roasting of an uneven sample presents certain difficulties and the presence of very small or broken beans gives the sample a poor appearance.

It should be the aim of the grower to produce an even, well-coloured sample, free of odours or flavours. Bean size is not as important as evenness of size, attractive appearance and freedom from flavours or odours.

The processed beans are packed by placing in double bags. Total weight of a packed bag should not exceed 180 lb. Clear and careful marking showing grade, number of bag and name of the plantation are necessary. A plantation name or mark which is well known and represents a first-class product can be a most valuable asset to the owner.

Territory robusta coffee is sold privately or through agents to buyers in the main eastern Australian cities. Before purchase, the coffee is sampled and tasted by liquorers and offers made for the shipment. The tasters will give a report on the sample used and the grower is strongly advised to take note of these reports, especially when off flavours or odours are said to exist. The rapid elimination of even a faint off flavour can mean the earning of a good name for your product, and as a result a premium price and a ready market.

PLATE 1.—*Hilling up new yam garden.*

AGRICULTURAL YEAR AT YABOB VILLAGE

J. R. VICARY

In August, 1948, the author, District Agricultural Officer at Madang, and his staff began a systematic series of observations of native agriculture at Yabob Village, near Madang. The area surveyed was only a short distance from a major centre of population and the time of the survey was during the period of postwar reconstruction, so it was thought likely that methods of agriculture would have changed. However, a shorter observation made in 1960, a description of which follows the main article, shows that the basic native agriculture is substantially the same. As a systematic record of native agriculture at a particular time, Mr. Vicary's account, written in 1949, is published for its general interest and to ensure that it receives a wider circulation.

THE village of Yabob, about four miles from Madang and about two miles from the District Agricultural Station, was selected as a suitable and convenient place in which to study native agricultural methods. The gardens are situated about a mile away from the village. A regular time—each Tuesday afternoon—was set aside for the visit to the village and either the D.A.O. or the cadet, or on some occasions both, visited the gardens each Tuesday, except on the few occasions when other work prevented it.

The natives as a whole were most co-operative and seemed proud that Agricultural Officers were evincing interest in their gardens and their methods of working them.

NOTES ON VILLAGE

Village organization

The Yabob population in 1948 numbered about 200 and was made up of the people of Yabob and the people of Kesup, a small village, which before the war was situated a few miles away. After the war, the Kesup natives abandoned their village and moved into Yabob. The people had seen Australian cities and military camps during the war and had decided they would probably be better off if they pooled their manpower and resources. However, they have since decided that their pre-war style of living in small villages is more to their liking.

Consequently the Kesup people have begun drifting back to their old village area to set up their own village and gardens.

House style

Houses in the village are all raised about 4 feet 6 inches off the ground and the average size is 30 feet by 15 feet. Most of them consist of two rooms and a verandah. House stumps are hardwood, but floor joists, rafters, studs and other construction members are either hardwood or softwood. The flooring is limbom palm and the walls are made of the midrib of sago palm, about 6 feet high. Leaf of the sago palm is used for the roof, which has a ridging of kunai grass.

Houses are laid out in an orderly fashion and are surrounded by small gardens of coleus, hibiscus, Chinese rose, crotons and bananas.

Young unmarried men have a separate house, but there is no house for single girls.

Transport

There is a good coronas (coral rock) road from Madang, but the road ends at the Gum River, the village boundary, which is not passable to wheeled vehicles. The people own no vehicles and women do all the carrying. When firewood or coronas is sold it is picked up by the buyer's truck. Every Saturday morning a privately-owned truck picks up produce for the Madang market. A few small canoes are owned, but they are not used to carry produce.

Land inheritance

Normally the male offspring inherits land, but if a man dies without a son his daughters may inherit a little land if they stay in the village. They lose this land if they marry into another village. If a daughter marries, either from her own village or outside the village, and continues living in Yabob, the husband can work the land but does not own it. However, on the husband's death, the land passes to his sons.

Trade

The main trade of this village is in garden produce to Madang for both Europeans and natives, in clay cooking pots and in the sale of coronas and firewood. Coronas brings in about £150 a year, while firewood returns about £25. It is estimated about 40 tons of garden produce a year goes into the Madang weekly market.

PLATE 2.—*Yabob headman's house.*

The people are not canoe-makers and the few canoes they own have been bought, either from Siar Village, a few miles north of Madang, or from Kranket Island, at the entrance to Madang Harbour.

The main article of native trade is the clay cooking-pot, which the women make from either red or black clay. The women dig a suitable clay, pick out the small stones, mix water and black sand with the clay and allow it to dry a little. Next they roughly shape it into a solid piece, then use a water-worn stone held in the pot

PLATE 3.—*Pre-firing of clay cooking pots, a Yabob industry.*

and a flat board outside to shape the pot. The pots are sun-dried for about two weeks and placed in a house for two to four weeks. They are then painted with a bright red-brown puddled clay and firebaked. Six sizes are made and they sell from a shilling to 12 shillings each, although most of them are bartered for other goods such as skirts, carrying bags, canoes, pigs, wooden plates and meat, such as fish and fowls. One woman can turn out from 10 to 12 pots a week.

Dogs' teeth and boars' tusks are still used as currency and although prices vary a shilling for a dog's tooth and 10 shillings for a boar's tusk would be average prices.

VILLAGE GARDENS

Half-way through the period of observations, 10 different garden areas were being worked, eight of them being new gardens started in the current season and two of them old gardens, started in 1947.

Each year new ground is cleared and planted and these gardens are worked only for about 18 months. In 1947 they had two large gardens totalling 20 acres and many individual gardens covering about six acres, a total of 26 acres of garden.

In 1948 eight new gardens covering 40 acres were made and the small individual gardens were abandoned, so at the half-way period of the observations there were 40 acres of new garden and 20 of old garden for a total of 60 acres.

The gardens are worked so that each is under cultivation during two wet seasons and one dry season. For instance, in August, 1948, it was estimated there were 26 acres under cultivation. In December there were 60 acres. In August, 1949, there were about 40 acres. In spite of the population decline through the departure of Kesup people, twice as much land was prepared in new gardens in 1948 compared with 1947. The largest garden at the half-way time was one jointly owned by Yabob and Kesup, which covered 15 acres. It comprised a flat planted in taro and a ridge with a south-west aspect under mami. Additionally, the Yabob people made six smaller gardens covering about 20 acres, while the Kesup people had made a single five-acre garden.

System of working

The "councillor in charge of gardens" is the person who selects the areas for the new gardens and decides the times for working them. Men, women and children start the clearing and work together until the area is entirely cleared and marked out into plots. The planting may be done either by the family responsible for the plot, or it may be a communal job. Once started, the plots become the responsibility of the family to which they have been allotted and each family does its own tending and harvesting.

The gardening calendar is worked out according to the seasons, which are the wet north-west from January to June and the comparatively dry south-east from July to December. July is normally fairly dry, so the clearing of the garden

is started then. One of the new gardens started in July, 1948, was chosen as the subject for study.

Women and children started clearing the undergrowth with knives and when this was completed the men cut down the timber leaving stumps about four feet high, which were not grubbed out. The only timber removed was the limbom palm which was cut for flooring and some straight poles for house building. Everything else was left lying on the ground. Secondary growth was heavy, as the ground had not been used for about 10 years.

During August, the cut timber and undergrowth dried out and no work was done in the new garden.

Early in September, the trash was considered dry enough and fires were started. After the first fire had swept through, some trunks were kept for marking out plots, then everything else was cut, stacked and burned again. This left only the larger logs, which were later cut for firewood for sale.

The garden was not fenced as, although there were some wild pigs and deer, they appeared to do little damage. The people do not plant sweet potatoes or tapioca in the early stages as they claim these crops attract pigs and the effort of fence building is not justified by the little extra variety in diet which sweet potatoes or tapioca would give.

Immediately after the fire, tobacco was sown. This was done by tying a whole head on to a pole about 10 feet long with about three feet of twine. The poles were then stuck in stumps and the wind scattered the seed on to the ashes. The seed was not covered by hand and germinated after the first rain.

The new garden, of about 3½ acres, had a south-westerly aspect, with a sharp rise of about 35 feet towards the centre. It was decided to plant the high portion under mami as the main crop and the lower portion predominantly with taro. However, both major crops were to be interplanted. Marking out the plots began immediately after the fire. Three straight paths were made through the garden and individual plots were then laid out and marked by timber lying on the ground. One man was allowed to own more than one plot in a single garden and could also own plots in several gardens.

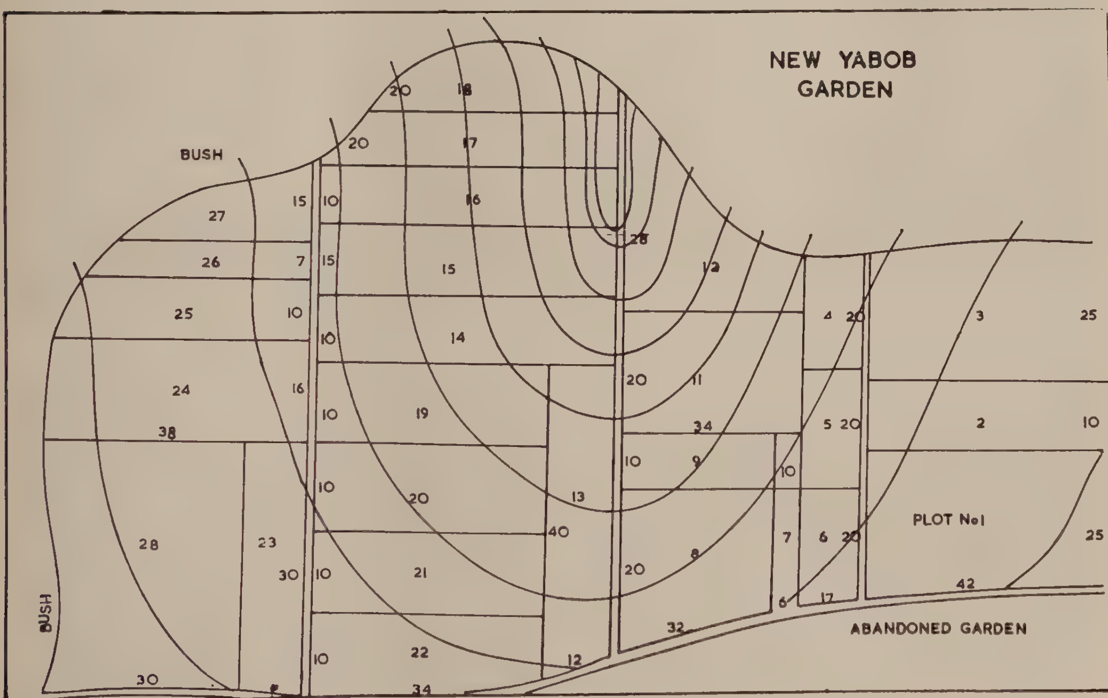


FIG. I.—*Diagram of new Yabob garden. Note contours.*

Planting of taro, banana and maize began in September while burning and marking of plots was still going on. The taro suckers were spaced about two feet by two feet and planted by being placed in a hole about a foot deep, made with a digging stick. Soil was not immediately filled in around the sucker because the people say the taro sucker rots if soil is filled in and consequently the hole must be left open for about a month. The banana suckers and maize were planted haphazardly through the taro. The banana was also planted in a hole made with the digging stick, but, unlike the taro, the earth is tamped around the sucker.

Mami is planted after it has begun to shoot, but if the stored mamis have developed long shoots, these are usually broken off just before planting so that a strong new shoot is on the tuber. A shallow hole is made and according to size one or two mamis are placed in this, shoot up. A mound two feet across and one foot high is then made, with holes over the tubers. The centres of the mounds are three feet apart, so that the edge of one mound almost touches the edge of the next. The mounds are never made before the mami is planted.

Most of the small amount of yam which was planted consisted of whole small tubers, but a few large ones were cut to eyes and used. A shallow hole was made and the yam placed in this and covered, no mound being made. The reason given for this was that yam tubers tend to grow downwards and therefore need no mound while mami tubers tend to grow upwards and need a mound of soil.

PLATE 4.—*Fenced taro garden.*

By the end of September, all the taro had been planted and sugar-cane, pineapple and "pit" (*Saccharum edule*—a wild sugar-cane with an edible inflorescence) were being planted.

Most of the native gardeners planted sections of sugar-cane three nodes long, half in and half out of the ground at an angle of 45 degrees. Long sections of the top of the cane were also planted, but in some cases a short piece of cane was laid flat and completely covered.

Early in October a start was made planting yam and mami on the higher ground. Most of the crop was mami and only a little yam was planted.

When planted, a thin three-foot stick was placed near each set for the first shoots to grow on, but this was later replaced with a heavier and longer pole. A second crop of mami is sometimes grown but a second crop of yam is never grown in the same ground as the people claim it is too hard on the soil.

In early November, mami, corn and bananas were still being planted and a few climbing beans and watermelons were also being put in. At the end of November nearly all the garden was marked out and planted. It consisted of taro on the lower portions, mami on the rise, with a few yams and interplanted with both were bananas, maize, watermelons, beans, sugar-cane and some self-sown papaws. From the time timber-cutting started until the garden was fully planted had taken five months. The garden was producing its first picking, the early maize, cucumbers, watermelons and beans.

In December, the eight-foot poles were placed for the mami vines to supplement the shorter sticks. The poles were placed on the edge of the mound and one pole served two mounds. A few poles were placed for yams, but mostly the small yam planting was left on the ground without any support. A little taro and maize were still being planted.

In all, the garden looked very well as mami and taro were making good growth, a few maize plants held some well-filled large cobs and, as it was a new garden which had been under bush, there was no growth of grass or weeds. The "pit" was growing well around the outside of the garden, where it had been planted because of its rank growth.

During January the garden produced maize, cucumbers, watermelons and aibika. Very few weeds were showing and those which appeared were pulled out. A little mami was still being planted and taro was being placed between the mami mounds.

In February the produce consisted of maize, watermelons, cucumbers and aibika. A few tomatoes and beans were also planted but most of the garden work had been completed by this month.

PLATE 5.—*A mami garden. This is one of the Yabob staples.*

March saw the harvesting of some of the taro, one of the two main crops and also maize, melons, cucumber, aibika and beans. Maize was planted in some places where the taro had been dug and some taro was planted where the maize had finished. A few peanuts also were sown.

During April the rest of the main taro crop was dug early in the month and other produce included melons, aibika, tomatoes and beans. There was no maize. Nothing more was planted in this month and as the garden was still free of weeds the only work was the gathering of produce.

In May, a little taro and some tomatoes and aibika were produced but nothing was planted.

During June a little taro and maize was produced and a few of the early yams and mami were dug. Again nothing was planted. This month the garden started to deteriorate as grass and weeds appeared, particularly where the taro had been and no attempt was made to keep this part of the garden clean.

In May and June production was low as this was the time between the two main crops of taro and mami. It was augmented by produce from the old (1947) garden which, during these months, produced taro, mami and crops which were not yet coming from the new garden, such as "pit", sugar-cane, pineapples, bananas and papaws.

During July the second main crop—mami—was dug and other produce included yams, taro, aibika, bananas, papaws, sugar-cane and peanuts. As soon as the mami was dug, the old vines were burned and taro was planted in the mounds. As the 1948 garden was now producing bananas, pineapples, papaws and other mature garden crops, the old garden was abandoned and a start was made on clearing for the 1949 garden.

OLD (1947) GARDEN

When the 1948 garden was commenced, the 1947 garden was in full production and supplying the village with food. In August, 1948, some yams and mami were being dug and the natives said these staples were not yet mature, but were being prematurely harvested to maintain a continuous food supply. Taro was also being dug and eaten. Maize was being gathered and the garden was also supplying sugar-cane, "pit", beans, pineapples, tobacco, melons, cucumber, aibika, tomatoes, bananas and papaws.

During September most of the remaining mami and taro was dug. Some of the taro was taken for planting in the new garden while some was replanted in the old.

In October and November mami was replanted in the same mounds from which it had been dug and taro was interplanted. No yam was replanted.

During December, when the rain started, some sweet potato was planted where mami and taro had previously been. Small mounds were made, but the number of runners planted in each mound depended on the individual's own ideas, varying from two to seven per mound. One-third of each runner was planted in the ground and two-thirds was left out.

A little taro was replanted but most had been planted in the new garden. No maize was being planted as it was all going into the new garden. At the end of December the old garden contained mami, taro, "pit", sugar-cane, pineapples, papaws, aibika and sweet potato. Beans, melons, cucumber, maize and tomatoes had finished and were not being replanted. All were now being put in the new gardens.

The old garden was still being weeded, but was not receiving much attention as all the work was going into the new gardens.

PLATE 6.—*Yams trained on vines attached to tree.*

Table I.

YABOB VILLAGE—GARDENING CALENDAR.

Month	Old Garden		New Garden	
	Planted	Harvested	Planted	Harvested
(1948) August	Taro, maize, melon, tomato, beans.	Taro, yam, mami, maize, sugar-cane, pit, beans, pineapple, melons, tobacco, cucumber, aibika, tomato, banana, papaw.	Tobacco, taro, banana, maize.	Nil.
September	Taro.	As for August.	Taro, maize, cucumber, melon, banana, aibika, sugar-cane, pit.	Nil.
October	Taro, mami.	Taro, maize, sugar-cane, pit, beans, pineapple, tobacco, melons, aibika, tomatoes, banana, papaw.	Mami, yam, melons, cucumber, banana, beans, maize.	Nil.
November	Taro, mami.	Taro, sugar-cane, pit, pineapple, aibika, banana, papaw.	Mami, yam, melons, cucumber, beans, maize.	Maize, beans, melons, cucumber.
December	Taro, sweet potato.	As for November.	Mami, maize.	Maize, beans, melons, cucumber, aibika.
(1949) January	Taro.	As for November.	Mami, taro.	Maize, cucumber, melons, aibika.
February	Nil.	As for November, with sweet potato.	Tomato, beans.	Maize, melons, aibika, cucumber.
March	Nil.	Taro, sugar-cane, pit, pineapple, aibika, banana, papaw.	Taro, maize, peanuts.	Taro *, maize, melons, aibika, cucumber, beans.
April	Sweet potato.	As for March.	Nil.	Taro *, melons, aibika, tomato, beans.
May	Nil, planting and weeding stopped.	As for March.	Nil.	Taro, aibika, tomato.
June	Nil.	As for March, and mami.	Nil.	Taro, aibika, mami *, yam, papaw, maize.
July	Nil.	As for March, and sweet potato.	Taro.	Mami *, yam, taro, aibika, banana, papaw, sugar-cane, peanuts.
				* Main crop.

Planting of new crops in the old garden continued until April, 1949, when it was nearly two years old. In July it was apparently rapidly returning to secondary growth and had become a tangle of kunai, saplings and scrub. Scattered through the regrowth was taro, sweet potato, aibika, papaws, bananas, sugar-cane, "pit" and pineapples, all of which were struggling for existence. At this stage the garden was abandoned and its produce was left for birds, flying-foxes and the occasional passer-by.

LABOUR IN GARDEN

The observations of the new garden were started on 10th August, 1948, just after the first clearing had been completed, so it was not possible to make exact observations of the numbers who had participated. However, I was informed that it took six men, four women and two children 10 days to clear the 3½ acres. Counting children as half units, this would give a total of 110 man days to clear the area.

The most people seen working in this garden at any one time was 11, six men and five women. The average number would be about six—three men and three women. Men do more work during the first four months than at any later stage. Once the clearing and planting has been done, most of the work is left to the women. Children have been seen in the gardens, but they do almost nothing.

Work in the gardens begins at seven in the morning and lasts until five o'clock in the evening. No meal is taken in that time but the workers refresh themselves with water, coconut milk or watermelon. No work is done on Saturdays and Sundays. From July to December, the estimated numbers of man days spent in the gardens are shown in Table II.

TABLE II.

Man days spent in garden per month.

1948		1949	
July	110	January	60
August	Nil	February	10
September	120	March	80
October	120	April	20
November	100	May	15
December	80	June	20
		July	80

Garden tools

In the initial clearing, light axes and bush knives were used. After the fire, the ground was not worked and digging sticks were used to plant taro and banana. A small stick was used to make holes for cucumber, maize and bean seed. Hoes were used to make mounds for mami. The sum of the implements in use was thus half-axes, bush knives, hoes and digging sticks.

GARDENING LAYOUT AND PRACTICES

The 1948 garden was laid out as shown in the plan (Fig. I). The area of approximately 3½ acres was divided by three paths into four sections containing 28 different plots which were looked after by four families containing 20 individuals. On the plan, plots are numbered and measurements are in yards.

Table III shows the contents of the various plots.

TABLE III.

Contents of plots in 1948 *garden.*

Plot No.	Contents
1	Taro, a little maize, self-sown papaw.
2	Taro, a little maize, watermelon and papaw.
3	Taro, a little maize.
4, 5	Mami, a little maize and watermelon.
6	Mami, little maize, melons and bananas.
7	Taro, few bananas, tobacco.
8, 9	Mami, few bananas, little maize, melon.
10	Mami, little maize, tobacco.
11, 12	Mami, few bananas, aibika.
13	Taro, mami, little maize, melon.
14 to 21	Mami, little maize, melon, tobacco.
22	Taro, few cucumbers, beans.
23	Taro, little maize, aibika.
24 to 28	Taro, little maize, melon, corn, cucumber.

Fertilizers

Little use is made of fertilizers or compost. After the initial clearing, everything is burned and when the planting is started the ground is bare and covered with a deep layer of ash. During tending, the weeds are sometimes thrown down where pulled, but usually they are thrown against a stump or out of the garden altogether. Use is made of the extra potash where stumps have been burned out and the humus around rotting stumps by planting beans, melons, cucumbers or tomatoes in those places.

Rotations

The theory of rotation is not understood. The people know, however, that some plants—yams for instance—will not grow two successful crops

in the same ground, so they do not attempt it. However, if a fairly good second crop can be obtained, then it is planted as soon as the first is harvested. This is done in the case of the two main crops, taro and mami.

Fallow or cover crop is not used at all and as stated previously the life of a garden is about 18 months. In this area there is no set time for leaving a garden under bush secondary growth. It may be three years or it may be more than the lifetime of those clearing it.

Storage

There is no great need to store food because gardening in this area is continuous. However, mamis, yams, and a little sweet potato, when it is grown, are kept. Mami and yams kept for food or planting are not stored in special yam houses but on the floor of the gardener's home. Taro is eaten when it is dug.

Seeds such as maize cobs, tobacco heads and so on are placed in woven carrying bags or just tied together and suspended from the rafters over the fireplace. Smaller seeds such as melon, cucumber, tomato and bean are put in tobacco or cigarette tins and again placed high over the fireplace to keep out insects and moisture.

Preparation of crops for foods and sale

The only cash crops are vegetables for the Madang market. Sweet potatoes are washed before being taken in, but mami and taro are merely brushed to remove soil. All other produce is sold as picked.

In cooking, the main dish resembles a vegetable stew. The major ingredient—yam, mami or taro—is peeled and cut up and to this is added beans, Chinese cabbage, tomato, pumpkin, tulip (*Gnetum genomon*), gathered from the bush, aibika and young maize. The stew is boiled in a cooking pot and the liquid is also consumed.

If fish is caught or a wild pig or a bandicoot is shot, this meat is added to the stew. Sea water is not used for cooking, as it was during the war, when salt was not available from local stores.

Eggs are eaten hard-boiled. Dogs and cats are not generally eaten now, although the older men occasionally like some.

The better varieties of bananas are eaten raw. Others are sliced and added to the stew or baked in the fire. Green maize is boiled, while the hard, ripe maize is baked in the fire.

No medicinal plants have been seen in the garden and the people say they do not grow either medicine or fish-poison plants. *Hyptis*, used for scent, is grown around the houses.

CROPS AND YIELDS

By measuring areas under different crops, considering planting distances and weighing produce an estimate has been made of the percentage and yield of each crop in an acre of interplanted garden. The measuring is neither easy nor accurate because, apart from the number of different plants in the garden, the fact that some plants are immediately planted when something else is taken out means that the percentage is continually changing.

However, Table IV shows what is considered to be a reasonably accurate list of the crops grown, the percentage of each crop in the garden and the yield of each crop per acre of interplanted garden per annum.

TABLE IV.

Crops and yields per acre.

Crop	Percentage of interplanted garden	Yield per acre of interplanted garden (lb.)
Taro	33	5,000
Mami	33	2,330
Sweet potato	4	480
Tapioca	2	200
Peanuts	2	17
Maize	7	140
Sugar-cane	4	2,240
Pineapples	3	580
Bananas	5	1,350
Papaws	2	1,350
" Pit "		20
Beans		100
Melons		150
Cucumber	5	50
Tobacco		10
Tomato		10
Aibika		200
Total yield per acre		14,230

The estimated total of 14,230 lb. of produce per acre means that this 3½-acre garden produced nearly 50,000 lb. of garden food. As 20 people were drawing their food from this, each one would have 2,500 lb. of food for consumption and sale. At a minimum of 4 lb. of garden produce per person per day for consumption, of

PLATE 7.—*Yabob fishermen using newly-introduced nets.*

this 2,500 lb., 1,460 lb. would be consumed and the remainder sold or traded. On these figures, one acre of garden can provide enough foodstuffs for nine people.

It is interesting to note that figures given in the local sample agricultural census, dated 4th June, 1948, which was conducted before this investigation started, are in keeping with the above figures. For a population of 239, there was a garden acreage of 26, which is about nine persons per acre. In addition to the garden produce, New Guinea people commonly obtain such things as coconuts, forest produce and fish and game.

DISCUSSION

The system of annual shifting agriculture seems wasteful, mainly of three things—manpower, timber and planting material.

While there is plenty of garden land available, and only a comparatively small native population to be fed from it, the system could hardly be classed as being wasteful of land. However, often land does deteriorate as a result of gardening. The scrub and grasses in the abandoned gardens are burned for hunting, which prevents timber re-establishing and also, in some areas, ensures the spread of kunai grassland by eating into the forest fringe.

Manpower is wasted by the annual clearing, burning and laying out of the gardens. If proper crop rotations could be developed it should be possible to use the gardens for a longer period. But there is no shortage of land and the native gardener prefers to spend a month cutting and burning a clearing than to spend time weeding and attempting to keep up soil fertility. With a new clearing, he has a good supply of humus and potash and at least a year free from grass and weeds.

When a garden is abandoned, it still contains plants, palms, canes and trees which are capable of producing food until choked out. This again is a waste, but as there is no shortage of planting material the practice could hardly be condemned.

The opinion is held that, considering the land available and the population that it is at present called on to feed, bush-fallow cultivation is wasteful mainly of one thing, timber.

YABOB—1960

[As a follow-up to Mr. Vicary's observations, another Agricultural Officer stationed at Madang, Mr. B. B. Johnston, visited Yabob Village in December, 1959, and January, 1960. He found a number of changes in the present way of life, compared with that of 10 years ago, particularly a greater dependence for cash income on labouring in Madang. The changes he noted are described below.]

Since Mr. Vicary's observations in 1948 considerable changes have taken place. The Kesup villagers have gone back to their own land,

leaving only the Yabobs. This move was completed in 1949-50. The Yabob village has been divided and half the population is now situated half a mile from the old village site at what is called Morelang or Yabob Nambis.

The Yabob population in 1949 was 167, it is now 246, which compares with the combined population (239) of Kesup and Yabob in 1948. Although the population of the area is almost the same is in 1948, the acreage of food gardens has dropped to approximately half of what it was then.

There are 39 people absent from the village at schools or for other reasons which leaves 207 who actually obtain food from these gardens. The people have also reverted to their old practice of having many small gardens scattered about the bush instead of the two or three big gardens as in 1948.

GARDENS—Crops and areas.

Mami	28 gardens	total 42,065 sq. yards.
Taro	15 gardens	total 14,800 sq. yards.
Tapioca	3 gardens	total 10,000 sq. yards.
Sweet potato	4 gardens	total 1,300 sq. yards.
		TOTAL 68,165 sq. yards.

i.e., 0.068 acres per head of population. This figure is very low and is just over half the 1948 figure. Most of the decrease would be due to the fact that few vegetables are now produced for the Madang market.

The clay cooking pot industry is not what it used to be either. The advent of relatively cheap aluminium saucepans has made a big difference and now clay pots are made and sold only when cash is required for some specific purpose, particularly on the part of the women. Most of the sales are to the Kranket people, near Madang, who are the traditional canoe-makers for Yabob.

Yabob is the closest village to Madang and consequently its labour line is the most accessible for any project in or around Madang, such as wharf labour or grass cutting. This, it is felt, is the reason why industries, which flourished in 1948, have declined to their present state.

With the stationing of a Fisheries Officer in Madang the villagers have been given the opportunity to establish a small fishing industry. Fish are netted in the Gum river estuary and on adjacent beaches and sold at the Madang market as either fresh or smoked fish. Fish caught during the week is smoked, but any caught early Saturday morning is sold fresh. Catches to date have been rather small and disappointing.

Copra is the only cash crop other than the odd net bag of vegetables and this is also at an all-time low. Yabob has 1,472 producing coconut palms, yet during 1959 only 1,144 lb. of copra worth £36 5s. was produced by two men.

From observation it is clear that as a whole the villagers prefer to earn their cash by labouring rather than by cash cropping.

Although drastic changes have occurred in the cash economy of these people, their traditional way of life has changed very little. Gardening techniques, laws of inheritance and methods of food preparation have not changed, although their diet is now supplemented a great deal with tinned meat, tinned fish and rice.

It is interesting to note that the price of clay cooking pots, dogs' teeth, pigs' tusks, etc., have not changed and still have their place in bartering and bride prices.

APPENDIX A.

Following is a list of scientific names of native food plants mentioned in the text. The source is the South Pacific Commission Technical Paper No. 94, *Food Plants of the South Sea Islands* (E. Massal and J. Barrau, 1956).

Garden crops.—

Taro—*Colocasia* spp.

Yam—*Dioscorea* spp.

Mami—*Dioscorea* spp.

Sweet potato—*Ipomoea batatas* (Pidgin : Kau kau).

Banana—*Musa* spp.

Pit—*Saccharum edule.*

Sugar-cane—*Saccharum officinarum.*

Aibika—*Hibiscus manihot.*

Papaw—*Carica papaya.*

Bush foods.—

Tulip—*Gnetum genomon.*

Sago—*Metroxylon* spp.

PLATE 1.—*Lightning strike damage on a New Britain plantation.*

COCONUT LIGHTNING STRIKE

A. E. CHARLES.

Lightning, a frequent hazard of tropical storms, is a major cause of coconut palm loss in Papua and New Guinea. The author, coconut agronomist of the Department of Agriculture, Stock and Fisheries, describes the death of 23 palms surrounding an observed strike in late 1956. He compares his observations with those made overseas and surmises that it is probable that the initial strike weakens the palm, permitting invasion by some pathogenic organism. Mr. Charles also says detailed study of the phenomenon is undoubtedly warranted.

IN coconut plantations throughout Papua and New Guinea numerous gaps can be found in the palm stand where groups of palms, varying in number from three or four up to 50 or 60, have died out. These gaps are roughly circular in shape and the losses are commonly attributed to lightning strike. Over a period of years, the loss of palms is appreciable and it is probably true to say that on plantations in most areas of the Territory losses due to lightning strike are greater than those resulting from any insect or disease attack.

Similar palm losses in Malaya were studied by Sharples (1933) who investigated particularly the possibility of palm death being the result of "bud-rot" caused by *Phytophthora.* He concluded that the symptoms observed were produced entirely by lightning or its after-effects. He considered that lightning is a factor of the first importance in the causation of loss in coconut plantations in Malaya.

Sharples described the typical case as "a group of 10 to 12 trees, of which one, two, or three central trees die rapidly. On examination the bud tissues are found to be in badly decayed condition. The surrounding trees show disease symptoms of varying intensity, e.g., stem bleeding, broken and hanging outside leaves, with the

central leaves and spike still standing erect. When left untreated some of the slightly affected trees gradually grow worse and finally succumb ".

He also quoted a specific case, where the actual lightning strike was observed, in which it was noted that some palms, which did not appear affected externally, died after a lapse of several months.

Dwyer (1936) discussed the occurrence of lightning strike in New Guinea. His observations are generally similar to those of Sharples concerning the symptoms shown by palms affected by lightning, but he also records the death of the bark and the presence of fungus species on the worst-affected palms. In addition, he observed differences in the prevalence of lightning strike in different parts of the Territory, which he relates to the nature of the terrain (as it influences the frequency of electric storms) and the soil type (occurrence of magnetic minerals).

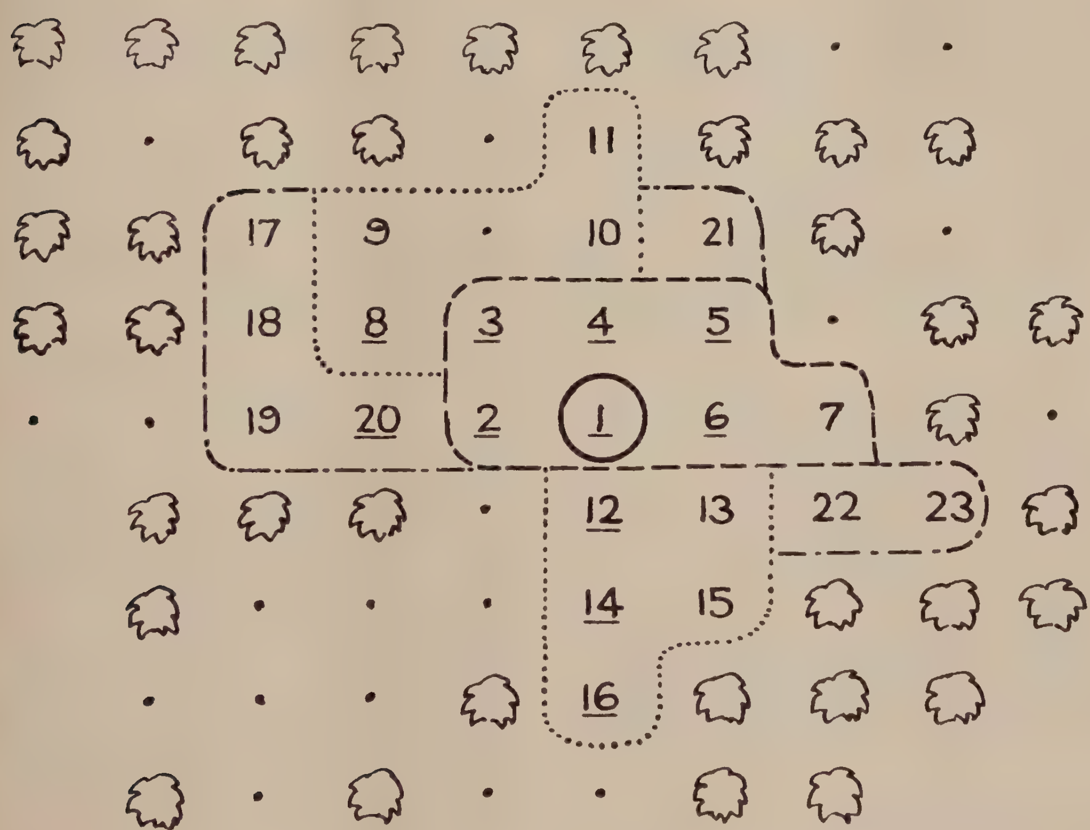
The present note is concerned with observations on a lightning strike occurring on a coconut plantation in the Gazelle Peninsula, New Britain. The actual strike was observed and observations at intervals afterwards over a period of 18 months show the sequence of events in which ultimately 23 palms died.

FIELD OBSERVATIONS

A plan of the area concerned is shown in Figure I. The palms which ultimately died are numbered, and surrounding palms which survived are marked by a palm-symbol. The palm stand is fairly old (at least 40 years) and many palms were already missing. These are indicated on the plan by a dot. Spacing is 30 feet on the square.

The lightning strike occurred on 29th November, 1956, and was observed by the plantation manager. A single palm received the main

FIG. I—*Plan of lightning strike.*



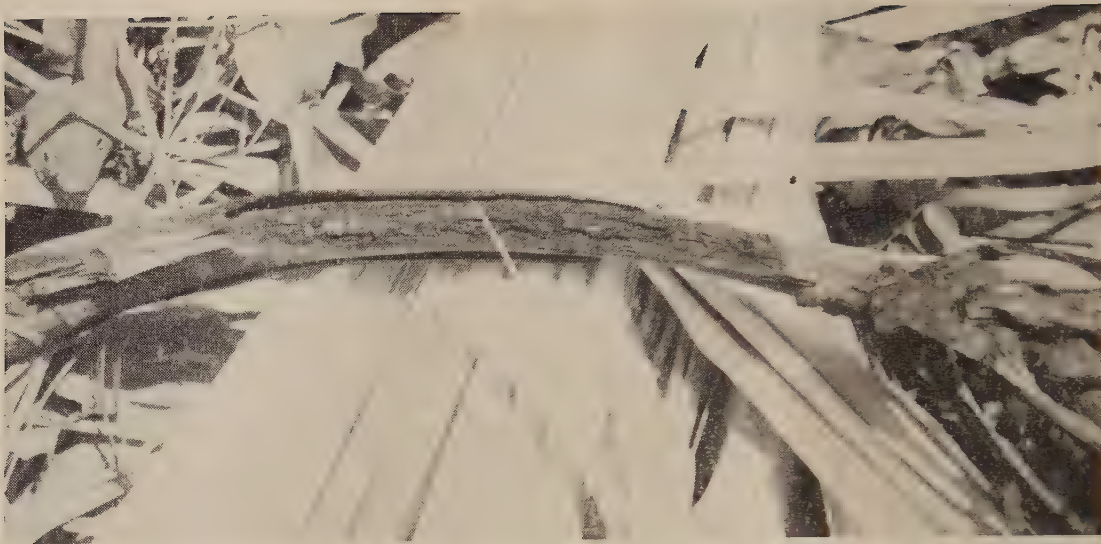


PLATE 2.—*Fallen spathe from a palm struck by lightning. Note charred tissue, evidence of fire, started at time of strike.*

force of the strike, as evidenced by a fire started in the grass at its base and a number of nuts of different sizes thrown to the ground. This palm is numbered 1 on the plan.

The area was first inspected by the writer five days after the strike. Palm 1 had all outer fronds hanging, while some of the central fronds, although still erect, were withered. There was no sign of damage to the trunk. Several nuts, in all stages of development, were lying at the base. All had brown scorch marks and most were split. Some of the surrounding palms had broken fronds but there were no other symptoms evident.

The palms were inspected again on 20th December, three weeks after the strike. The following notes were made :—

Palm 3 : Some broken fronds.

Palm 4 : Many broken fronds.

Palm 5 : One or two broken fronds.

Palm 2 : Several outer fronds hanging and a number of nuts shed.

Palm 1 : All but two or three central fronds hanging and dead, while the erect central fronds were withered. Almost all nuts fallen. Some of the old spathes, etc., fallen from the crown were charred.

Palm 6 : Most outer fronds hanging, and majority of nuts fallen.

Palm 7 : One or two broken fronds.

All other palms were apparently quite normal.

Another inspection was made on 8th January, 1957, about six weeks after the strike. Several more palms were now affected, as follows :—

Palm 11 : One broken frond.

Palm 9 : Possibly some fronds hanging.

Palm 10 : Possibly some fronds hanging.

Palm 8 : Several broken fronds.

Palm 3 : Some fronds hanging.

Palm 4 : Most fronds hanging.

Palm 5 : Two fronds broken.

Palm 2 : Most fronds hanging, and all nuts fallen.

Palm 1 : All fronds fallen.

Palm 6 : Central frond only remaining.

Palm 7 : Some fronds hanging.

Palm 12 : A few fronds hanging.

Palm 13 : A few fronds hanging.

Palm 14 : Most fronds hanging, and most nuts fallen.

Palm 15 : One broken frond.

Palm 16 : Most fronds hanging and most nuts fallen.

All remaining palms were unaffected.

Because of work in other districts, the area was not visited again until June, 1957, and then only general observations were made. More than 20 palms were now dead or dying, though several were only in the early stages of hanging fronds.

A detailed inspection was made again on 12th September, 10 months after the strike. All 23 palms numbered were now dead. Palm 18 was the only one with any fronds remaining as its central fronds were still standing. The rest of the palms were completely defoliated.

A closer examination of Palm 18 showed that the roots were apparently perfectly healthy. However, the bark on the trunk, except for a small patch at the base, proved to be dead and brown. Superficially the bark appeared normal, but at a depth of about a quarter of an inch the fibrous layer was dark brown and dead.

Surrounding palms all looked quite healthy, and none showed any sign of the dead bark found on affected palms.

A further inspection was made on 3rd January, 1958, 13 months after the strike. No more palms had died or showed any symptoms of disease, and it was concluded that there would be no further spread. This was confirmed in June, 1958.

However, an observation made in January was the presence of fruiting bodies of a fungus (*Ganoderma* sp. probably *G. applanatum*) on the stems of Palms Nos. 1, 2, 3, 4, 5, 6, 8, 12, 14, 16 and 20 and perhaps also on Palms 15 and 17. The affected palms were cut down shortly after this date.

DISCUSSION

Comparing these observations with those of Sharples, it is of interest that there was no stem-bleeding on these palms, whereas Sharples seems to have regarded stem-bleeding as one of the most typical symptoms. The only resemblance to stem-bleeding in the present instance came long after all fronds had fallen, when some gum exuded from the feeding holes of borers attacking the bark. This, however, is to be found in any dead coconut stem, whatever the cause of death.

Another difference is that Sharples mentions palms which showed some damage, but later recovered. In the present instance, on the contrary, at least 16 palms, which originally showed no sign of injury, subsequently died.

This delayed effect is of particular interest. If it were the growing point which was injured, it would be easy to explain a delayed effect, as the external fronds might continue to function. However, in lightning strike, the growing point is the last to die. It therefore seems probable that the mechanism of lightning injury involves an initial shock to the palm which weakens it and perhaps permits its invasion by some pathogenic organism. Such a pathogen would cause the gradual death of the palm.

It should be noted that, since in lightning strike the growing point is the last to die, lightning damage may be readily distinguished from "bud-rot" caused by *Phytophthora palmivora,* where the growing point is the first to be attacked.

Further investigation of the cause of delayed effects of lightning strike is undoubtedly warranted. Detailed studies should be made of the physiological changes occurring in the affected palms, as well as determining whether the effect is partly pathogenic. If there is a pathogen involved, it is possible that some measure could be taken to reduce the losses incurred. Various treatments, such as cutting back the fronds, ringbarking, or boring a hole into the trunks of palms around the affected area, are already used by Territory planters, but it is impossible to evaluate their effectiveness without controlled experiments.

The main difficulty in any such study is to find lightning strikes in the early stages, and it would be greatly appreciated if anyone observing an actual lightning strike (especially in the Gazelle Peninsula) would notify the Department of Agriculture, Stock and Fisheries.

REFERENCES.

DWYER, R. E. P. 1936. Diseases of the Coconut in New Guinea. N.G. Agric. Gaz., Vol. 2 : 28-93.

SHARPLES, A. 1933. Lightning Storms and their Significance in Relation to Diseases of (1) *Cocos nucifera* and (2) *Hevea brasiliensis.* Annals Applied Biology, Vol. 20 : 1-22.

INSECTS ASSOCIATED WITH DYING CACAO TREES IN WEST NEW GUINEA

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MANY cacao trees were dying and a number of insects were found in the Wosi Agricultural Experimental Garden, near Mankowari, in West New Guinea. Initially it was uncertain what caused the death of the trees.

Investigations revealed that 38 per cent. of the cacao trees of the clones M4 and M6 † used for generative tests were dead or nearly dead.

These field tests were being carried out on a yellow, lateric loam. In wet conditions the firm lower horizons are very sticky and the soil is hard to till. As a consequence of its firm, moderately pervious lower horizons and being in a flat area, the drainage of the soil is, as a rule, bad (Voort & Wentholt, 1943). Recently, physical tests at the laboratory of the Agricultural Experiment Station at Hollandia confirmed these field observations.

The average annual rainfall is 2,718 mm. (107 inches) and as shown in Figure I the wet season begins in November and continues until the end of May. After this the rainfall decreases until

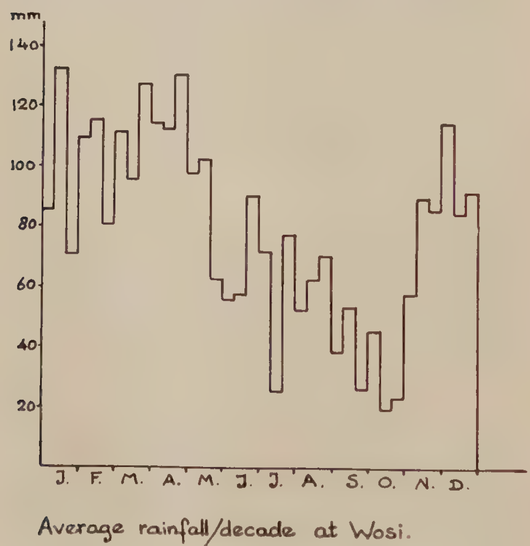

FIG. I.—*Rainfall recorded at Wosi.*

the end of October. This long wet season makes soil conditions very humid for a long period. After heavy downpours water up to 10 cm. deep lies on the ground under the cacao trees for several days.

The high humidity makes conditions very favourable for the fungus *Phytophthora palmivora* Butl. (synonyms : *Phytophthora faberi* Maubl. and *Ph. theobromae* Coleman). This fungus is an omnivorous tropical species, recorded on coconuts and queen palms in Florida (Westcott, 1950), on Hevea brasiliensis (Kunth.) Muell. Arg. in South-East Asia (Heubel, 1940) and on *Theobroma cacao* L. in Africa, Asia and New Guinea. At Wosi, *Ph. Palmivora* Butl. causes black pod and stem canker. After the fungus attack, the cacao trees appear to have symptoms similar to those caused by drought, despite the high humidity.

When the leaves first turn yellow, scolytids appear in the trees. Initially two species of Scolytidae, *Xyloborus discolor* Bldf. var. *posticestriatus* Egg. and *Xyloborus similis* Ferr. are observed. Both species can also attack healthy trees. X. *discolor* var. *posticestriatus* Egg., bores holes in the leaf axils. In 1924 this species was found in cacao twigs in Java (Kalshoven, 1959). *Xyloborus similis* Ferr. was found boring straight holes towards the centre of the branches of healthy cacao trees.

When the trees become unthrifty or die, a large group of insects will secondarily attack the branches and the stems. The following list gives the insects collected from dying and dead trees of *Theobroma cacao L. in March*, 1959 :—

Anthribidae :
- *Acorynus litigiosus* Pasc.
- *Feucus virgatus* Ford.
- *Phloebius gigas* F.
- *Plintheria luctuosa* Pasc.

Bostrychidae :
- *Xylopsocus capucinus* Fabr.
- *Xylothrips religiosus* Fabr.

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† Clonal numbers of the cacao used in the Wosi Experimental gardens.

Brenthidae :

One unidentified species.

Cerambycidae :

Clyzomedus fastidiosus Boisd.
Coptops illicata Pasc.
Exocentrus hispidulus Pasc.
Pterolophia duplicata Pasc.
Rondibilis spinosula Pasc.

Scolytidae :

Dryocoetes coffeae Egg.
Dryocoetes sp.
Xyloborus exiguus Walk.
Xyloborus fornicatus Eichh.
Xyloborus perforans Wol.
Xyloborus quadrispinosulus Egg.
Xyloborus semigranosus Bldf. females and possibly male.

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REFERENCES.

HEUBEL, G. AD. 1940. De bergcultures 32, p. 1,005 and 33, p. 1,036.

KALSHOVEN, DR. L. G. E. 1959. Tijds. v. Entom., vol. 102, p. 160.

SIMON THOMAS, R. T. 1959. Verslag dienstreis naar Manokwari en Biak (Internal report of Dept. Econ. Affairs).

VOORT, IR. M. VAN DER AND F. A. WENTHOLT. 1943. Contribution No. 6, Chou Noozi Sikenzyoo (Gen. Agric. Exp. Station). Bogor (Djawa), pp. 1-38.

WESTCOTT, C. 1950. Plant Disease Handbook. New York, Nostrand Co.

Port Moresby : W. S. Nicholas, Government Printer.—2944/5.60.